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Native Forests in the Nassawango Creek Watershed and Surrounding Areas: Piecing Together the Past and the Present A report presented to the Maryland/D.C. Chapter of The Nature Conservancy

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"The forests of the coastal plain have all been cut, at least once, by European man." (Brown et al. 1987).

"There are no accurate descriptions of the original forest on the peninsula ... What is known is that every patch of woods on the peninsula that exists today has been cleared and logged repeatedly." (Scott 1991).

"Since there is only the remotest possibility of finding stands of virgin forests in the Coastal Plain, one is faced with a jig-saw puzzle, within which the search for pattern is hopeless, unless he is willing to assume that the relative position of the parts to each other indicates the nature of the whole." (Quarterman and Keever 1962).

Abstract

What tree species, in what proportions were natural to the upland forests of the Eastern Shore of Maryland? Do any original old-growth forest remnants remain as examples? Pollen records, early eye-witness reports, historic land surveys, and present-day surveys were all used to address these questions. Most of the present-day upland forests are managed for pine. Oak trees were more common in the witness tree records and in the older existing plots. Maple and beech, both fire sensitive species, are more common today than in the historical records.

Introduction

On the East Coast of the United States is a peninsula of land surrounded by the Atlantic Ocean and Delaware Bay on the east and the Chesapeake Bay on the west. It is referred to as the Delmarva Peninsula because it is comprised of parts of the states of Delaware, Maryland, and Virginia. The landform is primarily a flat coastal plain. Maryland's portion of the Delmarva Peninsula is called the Eastern Shore.

Nassawango Creek is located in Wicomico and Worcester counties on Maryland's Lower Eastern Shore (Fig. 1); it winds for 15 miles through extensive upland and bottomland forests before emptying into the Pocomoke River. The Nassawango Creek has been a conservation priority for The Nature Conservancy since the founding of the Maryland Chapter in 1978. With more than 10,000 acres now in Conservancy ownership, Nassawango is by far the largest of the Conservancy's 30-odd preserves in Maryland.

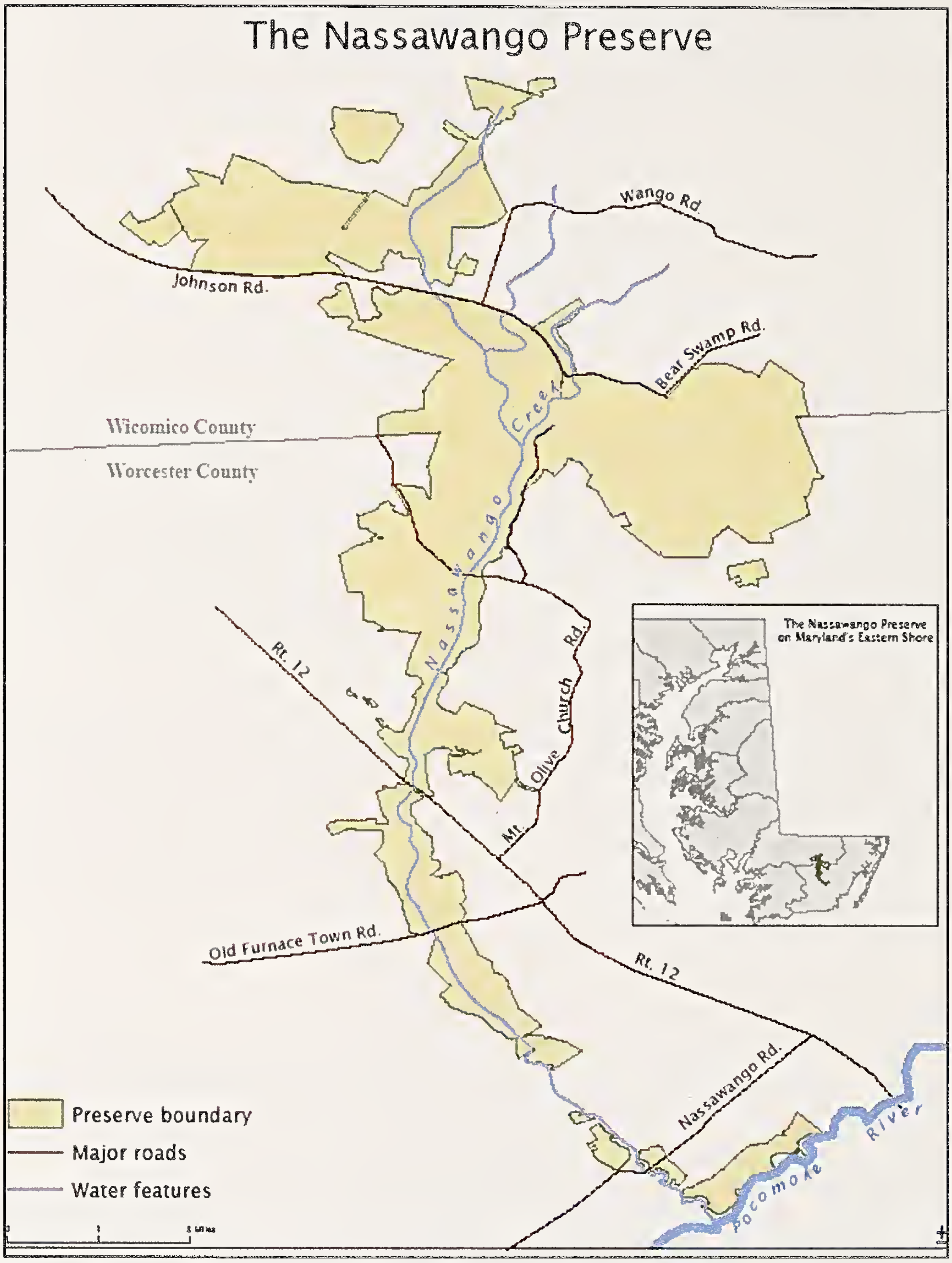


Fig. 1. Location of the Nassawango Creek Preserve on Maryland's Eastern Shore.

The Conservancy's early land protection activities at Nassawango focused on floodplain and bottomland swamp habitats along the main stem of the creek and its major tributaries, as well as on unique wetland communities that harbor multiple rare plant

and animal species. In the last six-eight years, however, the Conservancy has expanded its conservation focus to include large areas of undeveloped, contiguous upland forest in the Nassawango watershed and adjacent areas, with the ultimate goal of protecting habitat for all of the native species — common and rare — that still occur in the Lower Shore region.

To accomplish this forest biodiversity goal, the Conservancy has already acquired about 6,000 acres of upland woods in the watershed, most of which was used in the recent past to grow loblolly pines (*Pinus taeda*) for commercial timber and pulp production. A large proportion of these lands are still dominated by loblolly plantations in a variety of age classes. The Conservancy bought these lands with the intent to manage the existing loblolly stands until they reach marketable size, then commercially harvest the trees, and use that revenue to carry out a long-term, comprehensive, and carefully monitored native forest restoration program on thousands of acres in the watershed.

A fundamental requirement of this restoration plan is knowing what upland forest composition and structure to restore the forest to; that is, what species in what proportions were "natural" to the Nassawango Creek watershed and Lower Eastern Shore area? If we wish to attempt to restore any of these forests, we must use multiple clues to piece together some image of what they used to be. In this document, I describe my first attempts at gathering clues to describe how the forests of the Nassawango Creek watershed and surrounding areas might have looked before European settlement.

Accurately determining the kind of forests that were present 500 years in the past is a major challenge. Essentially all of the upland forests on the Eastern Shore have been logged or cleared several times since the area was first settled in the mid-17th century. A large portion of the upland area not cleared for farming was converted to loblolly timber and pulp production in the early 20th century, so regional forest composition has been shifted toward pine and away from hardwoods. Ditching of virtually all stream headwaters has altered both surface and groundwater hydrology, and thus the structure and composition of adjacent forest communities. Also, many animal species, such as bear, red wolf, and cougar, have been extirpated, while the abundance of herbivores such as white-tailed deer has increased substantially. Although beaver populations are rebounding — after near extirpation in the 20th century — their influence on hydrology, and hence forest structure and composition, is nowhere near what it was historically (Brush 2009).

Among the threads of evidence that collectively can be used to piece together a picture of what historic upland forests looked like on the Lower Eastern Shore are pollen records, early eye-witness reports, botanical collections, historic land survey records, species distribution patterns, present-day surveys, and old-growth remnants. I will discuss each of these briefly and add my own research findings, in a wide-ranging attempt to begin to piece together a description of the pre-settlement forest in the Nassawango Creek watershed and the region surrounding it. It is my hope that by com-

bining multiple spatial and temporal scales we will get the clearest possible image of what this landscape was once like and, consequently, what our goals should be for its restoration.

Clues from the Past

Pollen Record

Flowering plants produce pollen, which encases the male gamete in a shell-like case called the exine. The shape of the exine varies in different species, and it is often resistant to decomposition. Therefore, pollen deposited long ago can be "read" as a record of the past landscape. Other dating techniques, such as radiocarbon and lead-210, can date the layer where the pollen is found, providing a correlation between the date and the species present. Although the pollen record is very useful, it has its weaknesses. Some species, such as red maple, produce pollen that does not travel far from the source area (this explains why some species that are recorded as witness trees are not seen in the pollen record). Other species, like white pine, produce copious amounts of pollen, which travels long distance so it is very difficult to distinguish between local events and regional events in the pollen record. Nevertheless, pollen records are the most useful method for studying very long-term changes in the vegetative composition of the landscape. The deep pollen record tells us that the area surrounding the Chesapeake Bay has been almost completely forested for at least the past 6,000 years (Brush 2009).

In 2006, Brent Zaprowski (Salisbury University, unpublished data) extracted a 4.4 meter long sediment core from a cypress bog near the confluence of Nassawango Creek and the Pocomoke River. The bog, which is a few miles from the town of Snow Hill, Maryland, is an old channel meander of the Pocomoke River that is slowly filling in with organic-rich peat. Subsamples were taken from the core every 10 cm. and processed for pollen analysis using standard palynological techniques.

An examination of the pollen record at this locale shows that although the area was consistently forested, there have been large swings in the abundance of various species, even prior to European settlement (Fig. 2). For example, birch is relatively sparse (~2%) early in the record but rapidly expands around 500 A.D. Likewise, hickory is practically non-existent at the bottom of the core, but it rapidly increases to maximum value of ~14%, slowly declines and then reaches a stable level at ~800 A.D. which is maintained throughout the rest of the record. Most of the changes early in the record reflect past changes in the climate. Oak, which thrives in warmer, drier climates, shows a steady increase to maximum abundance during the Medieval Warm Period and then declines into the Little Ice Age.

The proportion of sun-loving weed-species pollen, such as ragweed, is frequently used to indicate the amount of clearing that existed in an area. The clearing could be

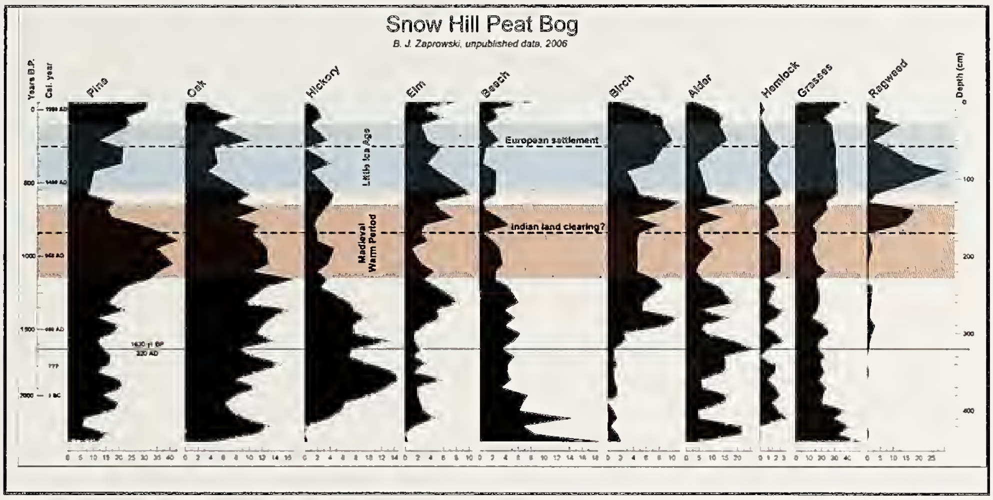


Fig. 2. Pollen records from a bog near the confluence of the Nassawango Creek and the Pocomoke River.

caused by humans or by other natural forces such as fire. Other regional palynology studies show an increase in ragweed around 1650, concomitant with an increase in European settlements (Brush 2009). Zaprowski's data, however, shows an increase in ragweed and grasses much earlier, around 1200 A.D. The sudden appearance of ragweed coupled with a rapid decline in pine and oak, along with archeological evidence of agriculture around this time, leads us to believe that indigenous tribes were likely clearing tracts of land before the Europeans arrived in the area. This is the first presentation of this data, and it has not yet been completely analyzed; however, it is an interesting and potentially useful thread of evidence.

Eye Witness Reports and Botanical Collections

A "pre-settlement" forest does not mean one that was not influenced by humans. Native people occupied the Delmarva Peninsula for thousands of years before the first witnesses who could write in English arrived. Early written reports tell us the landscape, just 400 years ago, was comprised of vast acreages of forest interspersed with villages of native people and their small agricultural fields — as was much of the East (see Hall 1910, Brown et al. 1987, Rountree and Davidson 1997, Hammett 2000, Brush 2009, and references therein). Trees were cut then, of course, but only for utility and sunlight, and not for commerce. From the descriptions it seems that most of those forests had the properties that we now associate with old growth: an open understory and some remarkably large trees (Hall 1910).

The accuracy of the early descriptions has been challenged by some who claim that they were exaggerations aimed at encouraging sponsors from the old country to keep financially supporting the expeditions (Hammett 2000). Others argue about whether the open undergrowth was caused by the dense shade of primary growth or

by burning (see, for example, Maxwell 1910, Russell 1983). There is also evidence from other regions that Eastern Woodland Indians created "nut groves" by encouraging food-producing trees, such as oaks and hickories, and removing other non-food species, such as black gum and sweet gum. To the early explorers these orchards may have looked like undisturbed native forests. Although Native Americans clearly influenced the landscape in the vicinity of their village settlements, large areas of dense uninhabited (and presumably unmanaged) forests also existed (Hammett 2000). Unfortunately, the 17th and 18th century descriptions of forests in this area are very general, and they contain no details of species range, spacing, or size. Therefore, it remains unclear if the forests first encountered on the Eastern Shore were forests managed by burning, forests managed by selective clearing, primary old-growth forests, or some combination (the most likely scenario).

In other areas of North America, and other areas of Maryland, the botanical collections of early naturalists provide unequivocal knowledge of what plants grew where. Some botanists were making collections in Maryland before Linnaeus developed his system of binomial nomenclature! Brown et al. (1987) compiled a summary of the vegetation of Colonial Maryland as evidenced by early botanical collections. Unfortunately, no records from present day Wicomico or Worcester counties were included. It appears that few collections were made from the lower Eastern Shore prior to the 1800s (Sipple 1994, Tucker and Tucker 2000). Where collections were made, the focus was primarily on herbaceous vegetation and, therefore, has limited use in determining native forest composition.

Witness Trees

Although there are no records of the relative abundance of various species in this region prior to the vigorous clearing that began with the arrival of the European settlers, trees were frequently used to mark property boundaries during the earliest official divisions of land. It is assumed that these trees, called "witness trees," were native and present at the time of earliest settlement. Examining the witness tree record has become a popular method of determining pre-settlement forest patterns (see for example; Cog-

Table 1. Frequency of tree species in witness tree records from western Wicomico County

Oak	544	Maple	4
Pine	161	Ash	2
Hickory	62	Cypress	1
Gum	39	Beech	1
Chestnut	9	Dogwood	1
Cedar	7		

bill et al. 2002, Rentch and Hicks 2005).

Witness tree records have never been published for the region surrounding the Nassawango Creek Preserve; however, historian John Lyon compiled records from 832 individual observations recorded between 1640 and 1710 from western Wicomico County (unpublished data). Current forest type distributions, as determined by Brush et al. (1980), are similar in western and eastern Wicomico County, so it is reasonable to assume that historic tree distributions would have been comparable as well. Oak, pine, and hickory were the most abundant trees in the witness tree records (Table 1). There are 39 trees identified as "gum," but no distinction is made between sweet gum (*Liquidambar styraciflua*) and black gum (*Nyssa sylvatica*), both very common trees in our present-day forest, and both easy to distinguish from one another. Another very common tree in present-day forests is red maple (*Acer rubrum*), but it is almost completely absent from the witness tree data. It is an early successional, fast growing tree, found presently in a wide range of soil moisture regimes. The apparent scarcity of red maples in the pre-settlement forests has been widely speculated upon (Abrams 1998). The most popular hypothesis is that fires were more frequent in the pre-settlement landscape, and red maple, being less fire tolerant than oak and pine, was at a disadvantage. The scarcity of beech (*Fagus grandifolia*) lends support to this hypothesis, as it is also fire sensitive.

Although the witness trees may not reflect the abundance of native trees perfectly (Black and Abrams 2001) it is important data which we include here as just one piece of the pre-settlement forest puzzle.

Early Forest Surveys

The first survey of forests in this area was completed in 1905 by William Bullock Clark for the Maryland Geological Survey. The surveys were done primarily for forestry purposes. The map of Worcester County forest areas was located, but despite visits to various libraries, no map was found for Wicomico County. The map for Worcester County shows areas that were cleared, areas of pine forest, areas of hardwoods and areas of mixed hardwoods and pine, and cedar and cypress (Fig. 3). Beyond those larger classifications, no species details were provided. Although the forest-type areas are difficult to discern on a map of this scale, I include it here to give an overall sense of the amount of forest already removed by 1905.

In 1910, Shreve published a volume about the plant life in Maryland. He provided lists of which tree species occurred in various regions of Maryland, but included no details such as tree size or spacing. Regarding the upland forests, in the region of interest to us here, he notes that 60-100 percent of the forests were composed of pine, with the pines decreasing in dominance as the forest aged, but never disappearing completely — even in the oldest stands. Shreve noted that, "there is no doubt but that the virgin forests of the lighter soils of the Talbot formation formed a mixed stand of pine and deciduous species." He mentions that the pines were a mix of loblolly and scrub, and

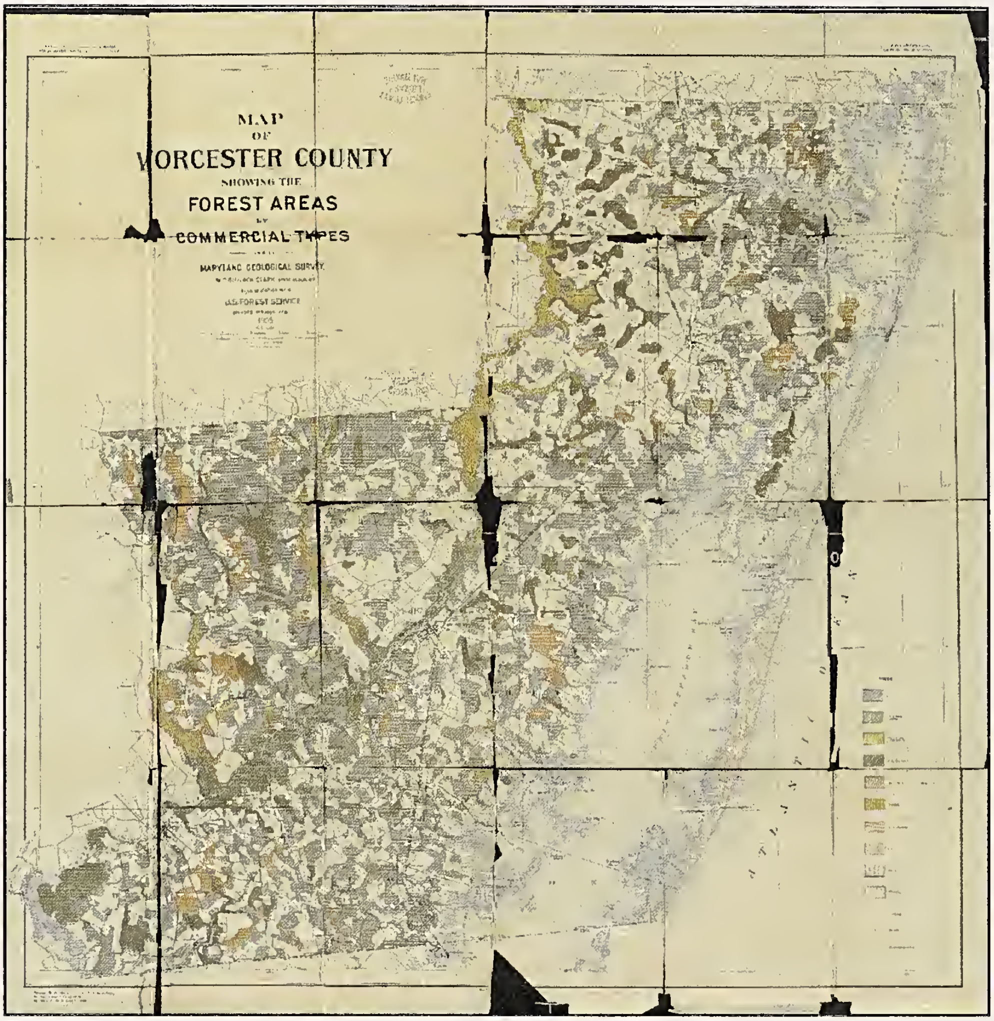


Fig. 3. First forest survey of Worcester County, done by William Bullock Clark in 1905. Blue/grey indicates pine forests, pink indicates mixed pine and hardwood, and brown indicates hardwood forest. An overlay of red stripes indicates that an area has been logged. Although details are difficult to discern at this scale, one may get an overall impression of the forest condition.

the deciduous species were primarily white oak and Spanish oak (these two making up 75 percent of the deciduous species), and the largest remainder of other deciduous species were other oaks and sweet gum. Red maple was infrequent.

The second forest survey was completed between 1907and 1914 for the Maryland Forestry Board (Besley 1916). Besley, the first State Forester, categorized the forests of Maryland into three different "types": 1) Hardwoods, 2) Pine (or Cypress), and 3) Mixed Hardwoods and Pine (or Cypress). Additionally, he lists estimates for the board feet of saw timber remaining in each stand. About Maryland's forest history he writes:

> "When the first settlers came to Maryland some 275 years ago, forest covered the entire land area of the State with the exception of the marshy areas which at that time probably comprised not over 5 percent. These forests were very different from those that now exist. The species of trees represented then were much the same as now, but their relative proportion has changed materially. The original forests were all of the hardwood type; now there is a large proportion of pine, especially in sections where land once cleared has been allowed to grow up again in forest" (Besley 1916:12).

Besley's statewide forest survey was organized by county, and the Nassawango Creek watershed, of interest here, occupies parts of both Wicomico and Worcester Counties. By 1915, only 46 percent of Wicomico County and 47 percent of Worcester County were still forested. This represents a loss of half of the originally forested area. At that time, in both counties, there were more than three times the board feet of pine than of hardwoods, most likely due to the presence of pine as an early successional species coming in after clearing.

I have reproduced and enlarged sections of the Wicomico County survey (Fig. 4) and the Worcester County survey (Fig. 5) that surround the Nassawango Creek Preserve. Even at this enlarged scale it is difficult to discern the classifications. Besley (1916) made reference to surveys drawn at a larger scale, but the original large-scale surveys were never located. Because his surveys were hand drawn, they do not line up exactly with present day satellite referenced surveys. Questions also remain regarding the sudden change in forest type across county lines. Nevertheless this forest survey confirms the first survey from 1905 showing large cleared areas and the remaining forest types as primarily loblolly pines and/or hardwoods.

Clues from the Present

Old-Growth Remnants Search

Although Quaterman and Keever (1962) are correct in stating that "there is only the remotest possibility of finding stands of virgin forests in the Coastal Plain," this project would be incomplete without a search for old-growth remnants. Finding any such remnant stands and characterizing their structure and composition would provide invaluable insight into historic forests.

Although true old-growth stands are very rare in the eastern U.S., they do exist and more remnants are discovered every year (Davis 2003). My search for old-growth forests had three components: 1) historical maps by Clark, 2) historical maps by Beasley, and 3) word-of-mouth. For this portion of the research, I widened the geographic scope beyond the Nassawango Creek watershed to include all of Wicomico and Worcester counties.

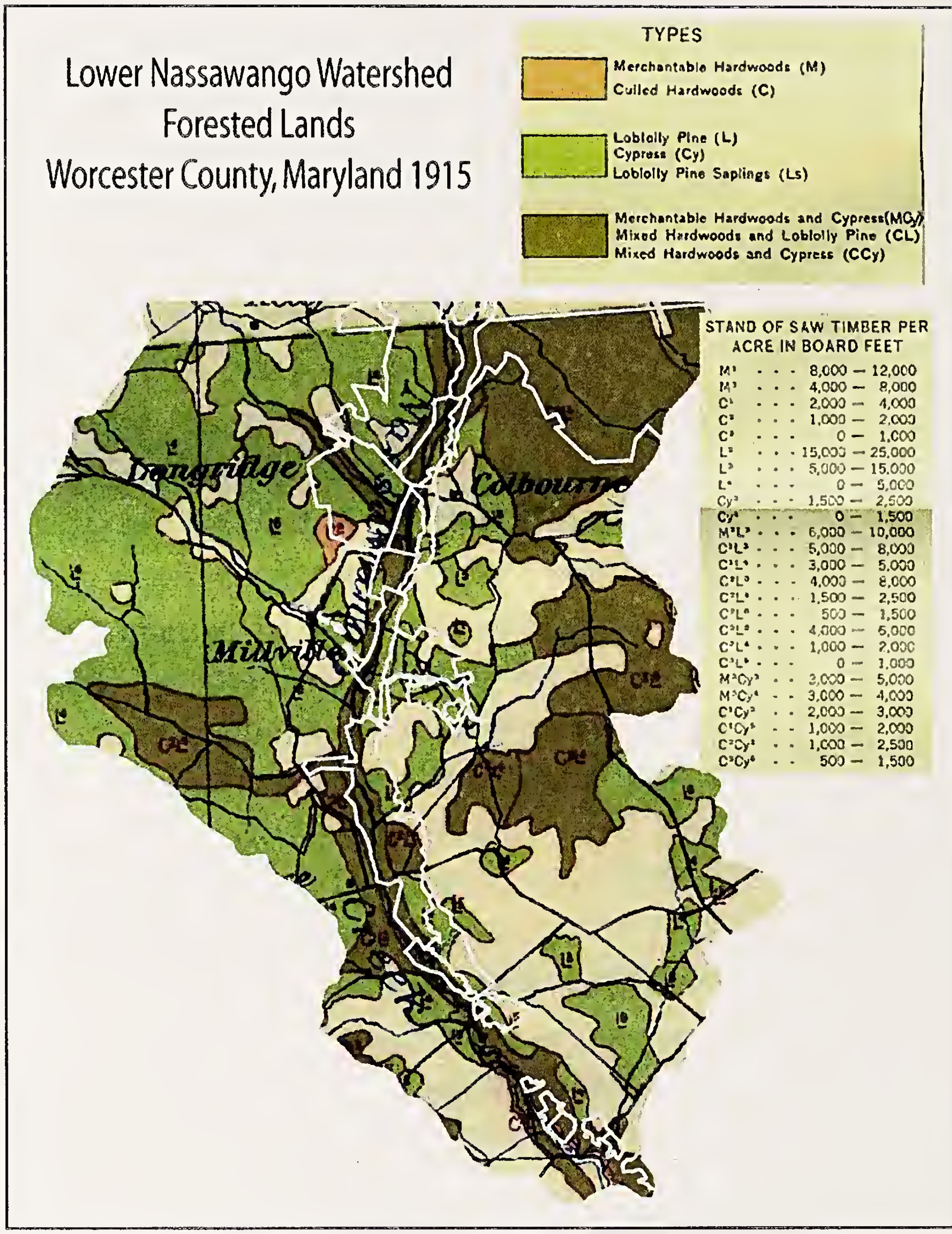


Fig. 4. An enlarged section from the Wicomico County forest survey (Besley 1916) showing the Nassawango Creek Preserve outlined in white.

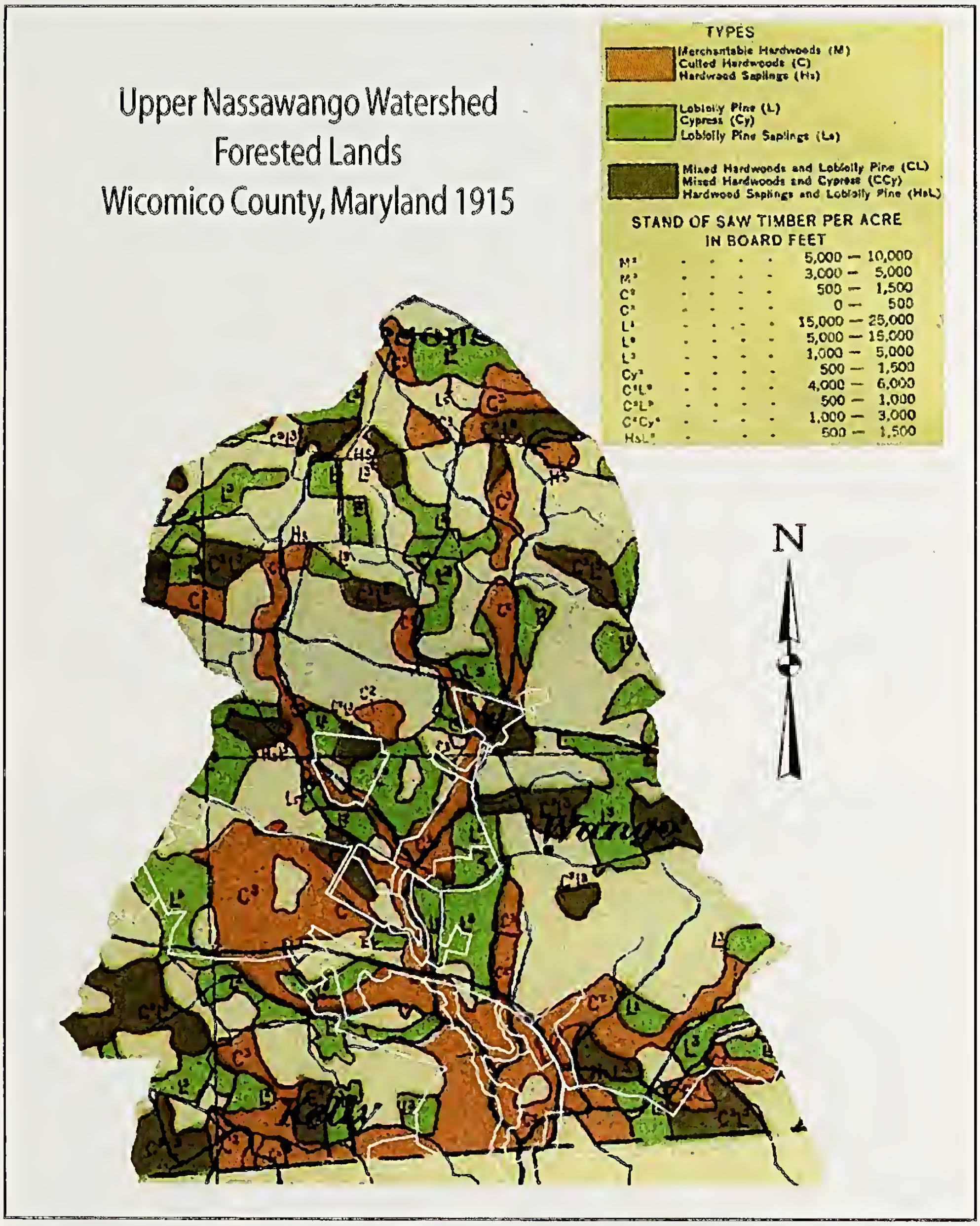


Fig. 5 An enlarged section from the Worcester County forest survey (Besley 1916) showing the Nassawango Creek Preserve outlined in white.

Fig. 6. Wicomico County forest areas shown as "merchantable" on Besley's 1915 map, overlaid onto 2006 aerial images.

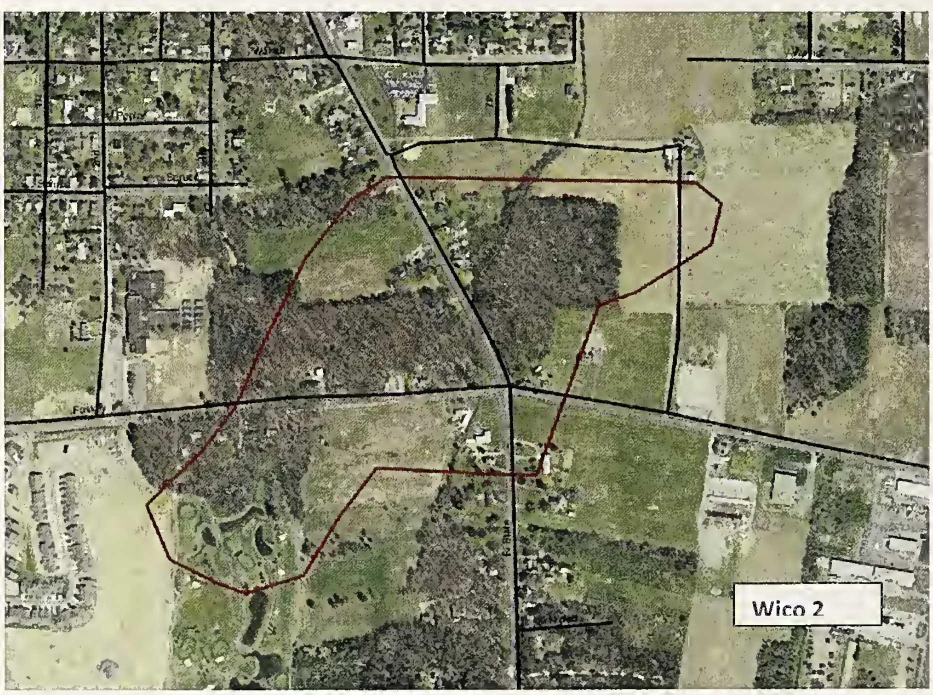
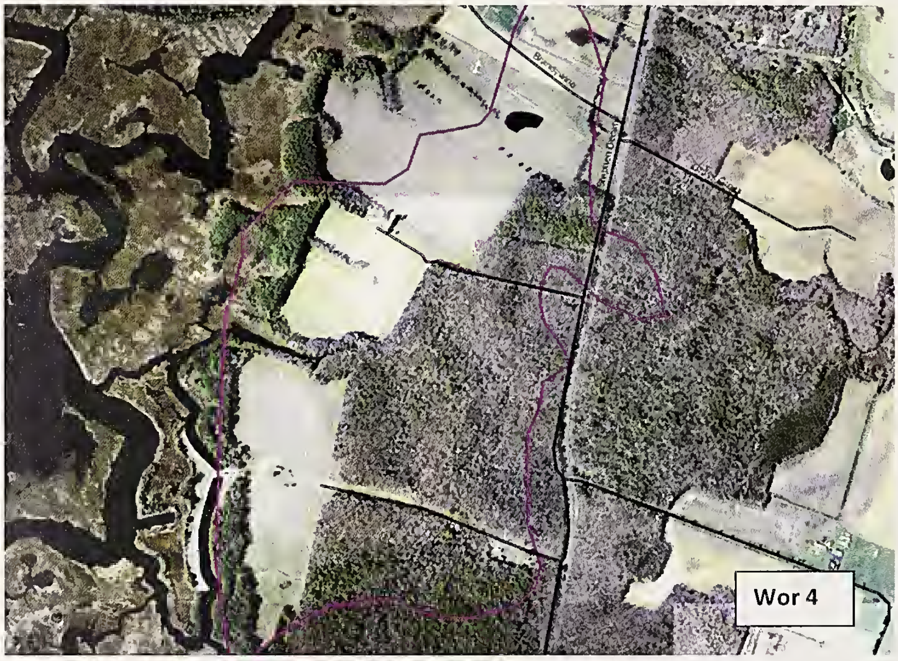


Fig. 7a. Worcester County forest areas shown as "merchantable" on Besley's 1916 maps, overlaid onto 2004 aerial images.

Fig. 7b. Worcester County forest areas shown as "merchantable" on Besley's 1916 maps, overlaid onto 2004 aerial images.



The 1905 Maryland Geographical Survey maps done by William Bullock Clark (Fig. 3) include the category "virgin," which I interpret as meaning that these areas were never cut, or even culled, and therefore they could be considered "primary old-growth." In Worcester County, only two small areas were included in this category. One area was just south of the Wicomico/Worcester County line at Whiton, southwest of Tilghman Pond; the other area was halfway between Pocomoke City and Whiteburg to the west of where Oak Hall and Whiteburg Road meet, but east of Fleming Mill Road. Wesley Knapp (Maryland DNR – Heritage, pers. comm.) inspected these areas on recent aerial photos and determined that they have been cleared and are currently managed as pine plantations.

Although Besley did not have a method of indicating original, uncut, forest, it is likely that any original forest would have been listed as M2 (merchantable hardwoods, 5-10,000 bd. ft./acre), or possibly L1 (loblolly pine, 15-25,000 bd. ft./acre). Note that there are no forests in these categories in the Nassawango watershed — indicating that there were probably no original forests of any extent remaining in the upland areas of the watershed at the time of the survey.

A close examination of Besley's maps shows only a very few parcels in the "merchantable" category, or with the highest amounts of bd/ft/acre. To determine where those areas were on the present landscape, and to determine if they were still intact, we scanned the maps from Besley's book and imported them into ArcInfo. The areas of interest were then digitally outlined and the resulting shape files were geo-referenced and overlaid on the orthographic mosaic photos of Wicomico or Worcester county. (The Worcester County mosaic was from 2004 and Wicomico was from 2006.)

Some of the areas had been completely altered, now containing farm fields or pine plantations, but we did identify two parcels of interest in Wicomico County (Fig. 6) and four parcels in Worcester County (Fig 7). Visiting these locations and surveying the forests (all on private property) was beyond the scope of this project, but a simple visual interpretation of the aerials suggests that remnant old growth is unlikely in most of the six locations given their small size, proximity to roads and fields, and obvious disturbances such as ditching and powerlines. Nonetheless, individual trees may survive from the time of Besley's survey and future visits to these sites are planned.

For the word-of-mouth information we contacted foresters and conservationists and asked to be directed to the oldest upland forests they knew of in Wicomico or Worcester county. All land ownership categories were included. Among those contacted were Gwen Brewer, Sam Bennett, Jason Harrison (Maryland DNR), Larry Walton (Vision Forestry), Joe Fehrer (The Nature Conservancy), Kate Patton (Lower Shore Land Trust), and Tom Horton (author). Additionally, there was a feature article about the project in the Daily Times newspaper (Ciarapica 2008) asking those with any information on old forests to contact this author.

Three forests visited as a result of word-of-mouth reports had the appearance of old growth (multiple large tree species of later successional stages, large snags and fallen

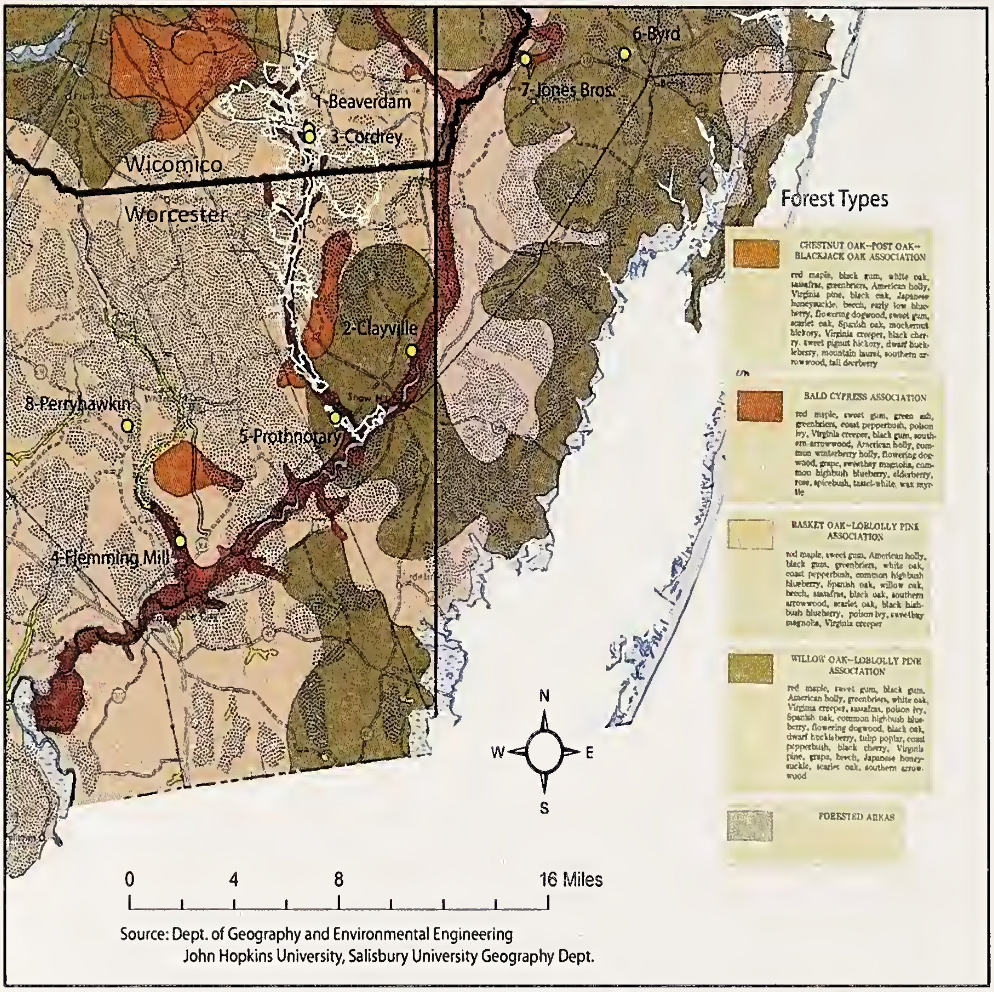


Fig. 8. Locations of the paired "older and younger" stands marked in yellow. The Nassawango Creek Preserve is outlined in white. In the background is the vegetation map from Brush et al., 1976.

trees). We named those stands: Cordrey – 3A, Clayville – 2A, and Prothonotary Trail – 5A (Fig. 8, and see below) ; Cordrey and Prothonotary are owned by The Nature Conservancy, and Clayville is privately owned. An examination of Besley's 1915 maps does not show those stands as being in the largest, "merchantable," category. The Cordrey forest, which has the visual characteristics of old growth, is listed as "culled" in Besley's 1915 survey. This may have been a light culling done in the 1800s, and it is highly probable that the forest has not been cut since then. By some definitions this forest would be considered old growth, but it is not "undisturbed." The slope on the Clayville Property along the Pocomoke River, and the slope on TNC's Prothonotary Woods along the Nassawango Creek, may have escaped logging entirely, but due to

the small area they occupy (less than 5 hectares), they are difficult to locate on Besley's map. At the very least, these three remnants were probably never clear-cut or converted to agricultural use.

No large forested upland areas in Wicomico or Worcester county appear to have survived completely intact from before 1915 until now. More in-depth historical research should be done in these three areas. Also, the areas described as "merchantable" by Besley should be inspected from the ground. (It was beyond the scope of this research to get landowner information and permission to survey the sites, but there are plans to accomplish that at some future time.)

Comparing Older and Younger Forest Stands

"As there are no virgin forests remaining, the nature of the climax forest must be deduced from successional trends, the oldest of the undisturbed secondary stands, and the few old trees which antedate settlement." (Braun 1950).

Various authors have commented that, in general, the variety of forest species has not changed greatly since the forest conversion began (Brown, et al. 1987, Dyer 2006), but the abundance of various species and the structure of the forests have changed. In this section, we compare present day older and younger forest stands with each other and with the witness tree records.

Materials and Methods

Eight forest stands in the Pocomoke Watershed were identified as being "older" through word-of-mouth reports or my own knowledge of the local forests (Fig. 8). These eight stands included the three previously mentioned that appeared to have old growth attributes. One stand was dropped from the analysis (Fleming Mill) because no comparison stand was located. Each of the older stands was paired with a younger stand nearby for comparison. Although it was beyond the scope of this study to determine the years-since-disturbance for each of these plots, they were judged to be older or younger by a visual inspection of the area which included considerations of tree size, species, spacing, presence of stumps, and of dead wood. This was a qualitative judgment based on personal experience in forests of known ages ranging from young pine plantations to true old growth. Each pair that we identified was older or younger *relative to each other*, and it is possible that a "younger" plot from one pair was actually older than an "older" plot from another pair. Although this methodology is far from perfect, we used it to examine successional *trends* and not absolutes, and for the purposes of this study, we will identify the halves of each pair as "older" and "younger."

All plots were not in forests of the same community type. For this study we were most interested in upland forests, so true wetland forests were not included; but because older upland forests are so rare (most having been cleared for agriculture or building), some of our sites could be classified as "mesic" rather than true upland. Furthermore,

because the remaining older upland, or mesic, sites tend to be rather small (sandwiched between wetlands and agriculture or development), we were restricted in the size and shape of the plots we could use. We found that a single long transect could often not be aligned randomly or it would leave the representative forest area. But a single square or rectangular plot did not seem to represent the diversity of the surrounding forest. An X-shaped plot, composed of two transects, was our preferred solution.

A representative spot was chosen in an older stand, and this center position was flagged and recorded by GPS. From this spot, a random direction was chosen for the first transect axis. A tape was stretched 25m in each direction from the center point (50m total) and data was collected one meter from both sides of the tape (2m total). Another 50m transect was established 90° from the first transect and crossing at the center point. The result was a (200m^2) X shaped transect. Within this transect every woody plant over 2m in height was considered a tree and its species, diameter at breast height (dbh) and position along the transect was recorded. If the tree was dead, it was identified as a snag and dbh and position was recorded. All woody plants under 2m were considered seedlings and only species and counts were recorded.

Younger plots were chosen within 500m of the older plot, in a forest which appeared to have been cleared more recently, yet which would have likely contained the same forest type. Transects were established and data collected in the same manner as described above. Trees in plots designated as "older" and "younger" were compared by paired T-tests.

Results

As expected, the mean dbh of the trees in the older plots was greater than in the younger plots (Table 2). The mean total basal area was also greater in older than in younger plots, although this difference was not significant. Number of trees per plot was smaller in the older plots. None of these results are very surprising since numerous researchers have found similar results: fewer, larger trees in older stands (Lapin 2005). Indeed, these plots were selected on a visual estimation of these criteria. The number of tree species did not differ at all between the two plots. The number of snags per plot was, surprisingly, higher in the younger plots, although this difference was not signif-

Table 2. Comparisons between "older" and "younger" 200 m^2 (n = 7) plots of forest in the Pocomoke River Watershed.

	Older	Younger	*p*
Mean dbh (cm)	17	12	0.05[a]
Basal area (cm^2)	1275	890	0.13
Mean # trees .	29	50	0.04[a]
# Species	6	6	1.00
# Snags	1	3	0.19
Mean dbh snags (cm.)	16	12	0.35

[a] significant differences, two-tailed T-test.

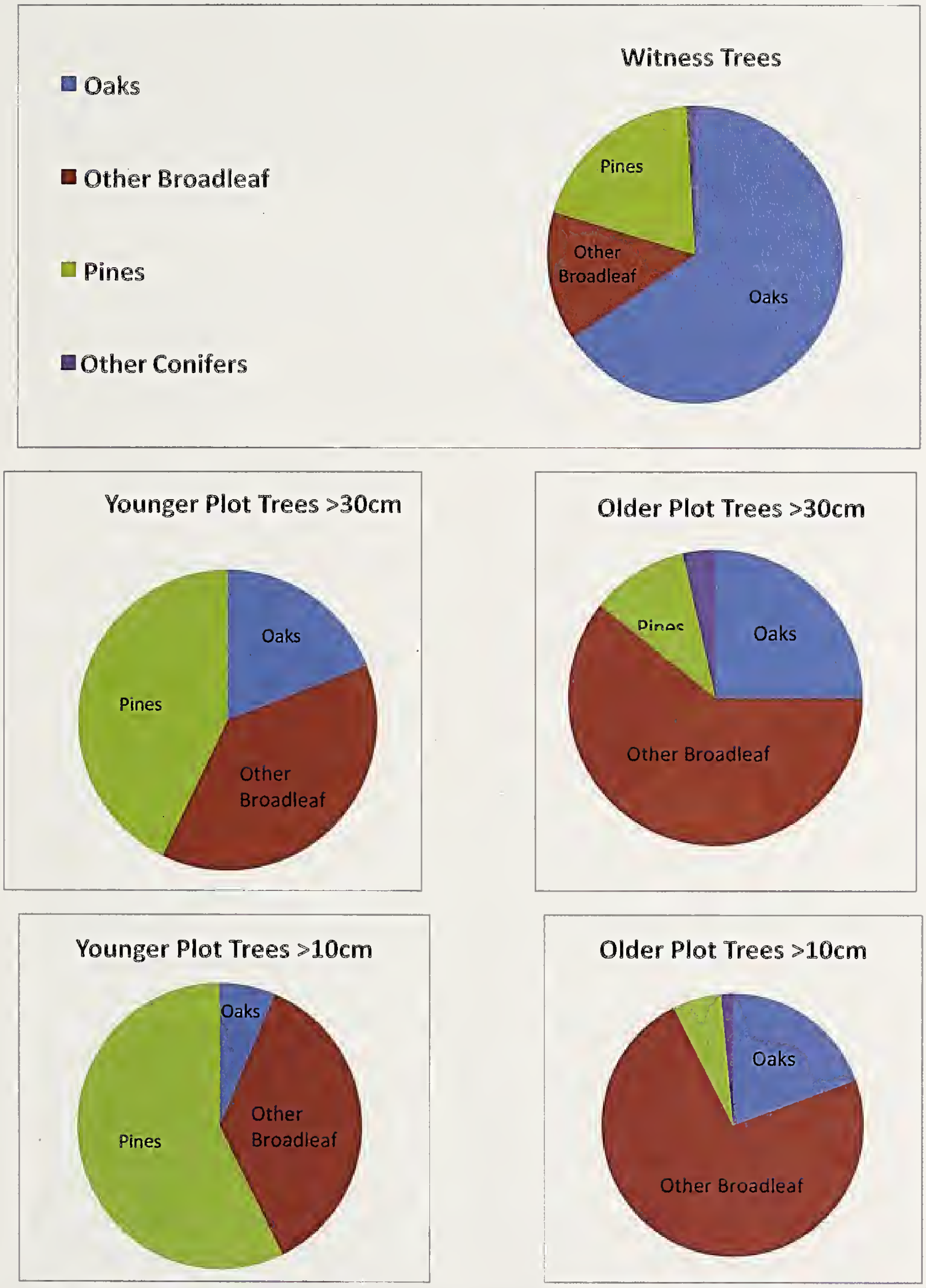


Fig. 9. Comparison of species abundance in witness tree records and "older" and "younger" plots.

icant. The mean dbh of the snags in the older plots (unpaired T-test) was larger, although, again, this was not significant.

A total of 542 trees, of 22 species, were recorded in the 14 plots. The most common tree was holly (176), followed by loblolly pine (85), sweet gum (71), and red maple (50). Beech and paw-paw had the same number of occurrences (26), followed by swamp magnolia and hornbeam (10 each). The remaining 14 species occurred less than 10 times when all plot totals were combined.

Discussion

Although the witness tree data does not overlap with the plot locations, it might be useful, nevertheless, to compare the abundance of species found in the plots with the abundance of species selected as witness trees. Landform, soil types, and tree species are broadly similar in the region covered by the witness tree data and the region where my plots are located (See Fig. 8 and Brush 2009).

To simplify the comparison, witness trees and older and younger plot trees were counted in four categories: 1) oaks, 2) other broadleafs (ash, beech, chestnut, dogwood, gum, hickory, maple, poplar, hop-hornbeam), 3) pines, and 4) other conifers (cedar, cypress). Because hollies and a number of small understory trees (hornbeam, magnolia, sassafrass, paw-paw) were not mentioned as witness trees, they were excluded from the comparison. Also, because it is possible that only larger trees were selected as witness trees (but see references in Black and Abrams 2001 which discount this), to compare abundance the plot data was divided into only trees > 10 cm dbh (still a relatively small tree) and then again into only larger trees > 30 cm.

Unlike the plot data, the witness tree data recorded oaks as being the most abundant tree (Table 1). In my plots, the largest percentage of oaks was evident in the largest trees in the oldest plots. The smallest proportion of oaks was in the younger plots including the smallest trees.

Pines were much more common in the younger plots than in the older plots, as expected, because pines are quick to return after a disturbance, and it is likely that some of the younger plots were managed for pine, possibly with herbicide sprays and/or planting.

Interestingly, the witness tree data showed more pine than our older plots. One possibility is that pines were, in the past, an important element of the forest particularly on higher and drier sites. As those sites became settled and cleared for farming and building, the only forest land left was in damper areas that supported fewer pine. Sadly, we discovered not a single large (>100 acres), mature, upland forest in our research. (Although the Foster property, a recent TNC acquisition, remains to be examined.)

When one spends time with the abundance graphs (Fig. 9), a subtle pattern begins to emerge. If one accepts, provisionally, that the witness tree data are from the oldest forests, the largest trees in the oldest plots contains the next oldest forest, and the younger plots including small trees represents the youngest forest, then our axis showing

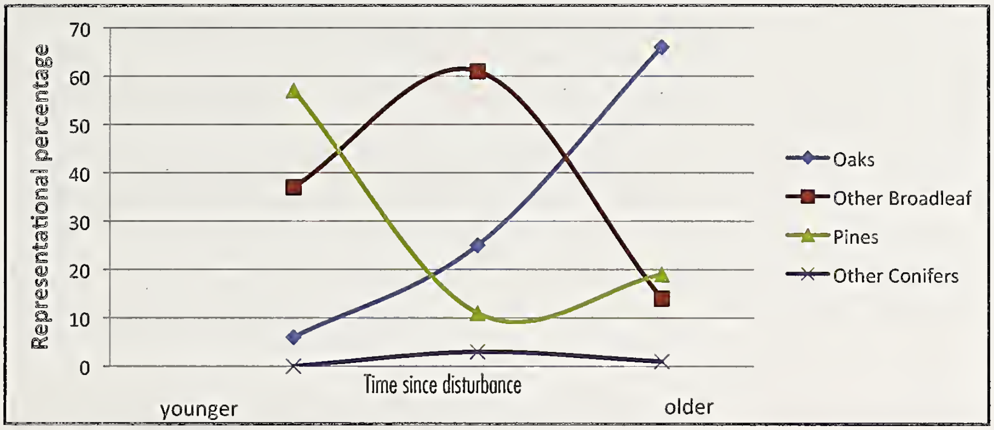


Fig. 10. One possible scenario for tree species change over time.

these three in order might be labeled "time since disturbance" as it is in Fig. 10. (Although the points would not be evenly spaced as they are shown here.)

Looked at in this way, the percentage of oaks in an upland forest steadily increases over time, while the other broadleafs increase over time until hitting a peak and declining (to be replaced by oaks presumably). The pines are abundant in the younger forest, decline steadily over time, but in the end, as the other broadleafs decline, a percentage of pines remain and become an important component of the pine-oak forest. This would be precisely the composition of the upland "virgin" forest described by Shreve (1910).

Summary

The strength of this study is the ability to look at the past and present forest through many different lenses. These are the "threads of evidence" that I have woven together. It was fortunate that a separate, as yet unpublished, study examined the pollen record so geographically close to our area of interest. It was again fortunate that a different study, also unpublished, recorded the witness tree records for a region close to our study area. Both the pollen record and the witness tree record indicate that at the time of settlement pine, oak, and hickory were relatively common, and beech and maple were relatively rare. It could be argued that maple is absent from the pollen record due to having pollen that decomposes quickly, but it is also rare in the witness tree record.

The species composition of the forest has also changed. It has gone from a forest of pine-oak and hickory (many of them probably quite large) to a bifurcated forest structure of either many young pines in a race with broadleafs for dominance, or an older forest where most of the pines have lost the race. Both prongs are different from the historical forests because fire-sensitive species, such as red maple, gum, holly, and beech, are more common today than they apparently were in the past.

Although we do not fully understand the effects that swings in herbivore populations, such as deer and beaver, may have had on historic forest compositions, the evidence is relatively convincing that drought and/or fire were influential in shaping the historic oak-hickory-pine forest and suppressing the other broadleaf trees that are so prevalent today (Kirwan and Shugart 2000, Howard 2005). While I did not address fire directly in my research, and the frequency and intensity of historical fires is a matter of some controversy, the witness tree data from western Wicomico County — the earliest real forest data we have from this area — points toward a fire-controlled landscape in this region at the time of settlement. Witness tree data from other nearby states also shows dominance by oak, hickory and pine (Russell 1981, Black and Abrams 2001) and, as in our area, contemporary forests in surrounding states also exhibit successional movement toward shade-tolerant, fire-sensitive, species (Stephens and Waggoner 1980, Abrams and Downs 1990).

What is less clear is the influence that humans have had on shaping the historic landscape. Were fire-sensitive species suppressed here in the past because of lightning-caused fires? Or, were they suppressed by fires started by native people, either purposefully or accidentally? Regardless of the answer to that question, we know that fire frequency increased immediately post-settlement in New England (Parshall and Foster 2002), and probably here as well. And without a doubt, forest clearing increased in speed and scope post-settlement, especially in this area where wood was needed to feed the mills and fuel the iron furnace. Our research shows that the forest is much smaller than it once was, both in area covered and in stem diameter. If any "original" upland forest exists here at all, it exists in only a few small corners.

The study comparing older and younger plots was one of the most difficult and time-consuming aspects of this research. First, mature, accessible plots had to be located (surprisingly difficult!), and then a younger plot in the same area had to be found. In one case, we found an older plot, but we could not find a comparable younger plot. In many other places, young plots existed, but no older plots. Even when we did find "pairs," they frequently varied in aspect and/or management history. In the end, this research did not reveal many useful indicators, possibly due to the variability between the plots and the small number of plots (seven pairs) compared. What we did accomplish with this study, however, was the development of our methodology. After extensive research on forest mensuration techniques, we established a procedure that was realistic in the field and useful to research teams studying various aspects of the forest (e.g., biological or structural or chemical).

But what does this research say about native upland forests in the Nassawango area? Unfortunately, it points more to what was lost than to what was found. We found no original, undisturbed forest larger than 10 hectares. We found no detailed descriptions of the original upland forests. In the few older remnants that had old-growth characteristics, the species mix was similar to that of the younger forests.

Future Research

This research is not complete, and perhaps it never will be. In other parts of the U.S., researchers have been working for more than a decade to determine pre-settlement forest patterns. To put this present work in context, it should be noted that this work was accomplished with one month of summer support for research.

There are a few pieces of the research that we are anxious to complete:

- Produce a witness tree map for eastern Wicomico and Worcester counties.
- Locate the 1905 Maryland Geological Survey map of Wicomico County (if one exists).
- Carry out a ground inspection of the areas of interest that were designated as "merchantable" on Besley's maps. (Some landowner information and permission has already been obtained.)
- Carry out a ground inspection of possible older areas identified by remote sensing.

Initial Thoughts on Restoration

Making specific management recommendations is beyond the scope of this project, but we can use the information gathered here to make general observations on what direction we will need to go to restore the upland forest landscape to a pre-settlement condition.

The current landscape of the Nassawango Creek watershed uplands — and, indeed, the majority of the Eastern Shore — is composed of many acres of pine-dominated forests in an early successional phase. The forests are dominated by loblolly pine with an undergrowth of red maple, black gum, sweet gum, holly, persimmon, oak, and other species. Fortunately, these are all native species that were historically present in the landscape in various proportions. Although the species historically found in the landscape are still represented (with the exception of the chestnuts), short-rotation logging (30-60 years) and forestry associated herbicide applications have prevented the broadleaf trees from assuming their historic role of co-dominance.

Since the pollen data and the witness tree data indicate that the area was predominantly pine-oak-hickory, one realistic restoration goal would be to leave some of the existing pines (a historically abundant species) and allow them to mature. The naturally occurring oaks and hickories could be encouraged through selective thinning. A companion paper (Maloof, this volume) describes the distribution of tree species in the Nassawango Creek Preserve, this mid-scale view of species distribution could inform the restoration process of other less common upland species such as river birch and beech. The dominance of fire-resistant trees in the pollen record and the witness tree record is evidence that fire was an important component of the pre-settlement landscape. Less fire-resistant species were always present, although in smaller numbers, in-

dicating that there were places that remained unburned. These unburned areas may have been islands of upland forest surrounded by wet areas; therefore, restoration goals should take landscape position of the forest into consideration.

Although pollen core data and witness tree data are very useful in determining historic species abundance, they are less useful in describing forest *structure*. In addition to a restoration of the historic species distribution, a restoration of the historic landscape structure should also be a goal. In some regions, existing old-growth forests can be used as models to illustrate the pre-settlement landscape structure. Unfortunately, our research uncovered no upland old-growth forests of more than a few hectares in size; therefore, most of what we can say about pre-settlement landscape structure is based on early eye-witness reports and primary forests in other areas.

The pre-settlement forest here likely contained larger trees, larger snags, and more coarse woody debris (all three important for animal species habitat) than exist presently. The canopy itself would have been "rougher" with gaps where large trees had fallen. Some of the areas would have been undisturbed for many centuries, but in other areas, wildfires would have scorched the ground regularly (either through lightening-strike started fires or through the actions of Native Americans). In those places early successional species would dominate the forest.

Vast acreages of forest on the Eastern Shore have been cleared for farms and development. To return our landscape to its historic condition, both the extent and the age of the forest cover would need to be increased. Since old forests are known to be important areas of biodiversity, there should be some upland forests left undisturbed, except through uncontrollable acts of nature, to encourage the structural components that only develop over long periods of time.

Perhaps someday we will be able to see a forest similar to that described by the earliest settlers. Perhaps then we will see the cloth instead of just the strands.

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A TREE SPECIES DISTRIBUTION SURVEY TO GUIDE RESTORATION

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ABSTRACT

Restoring upland forest to pre-settlement condition requires knowledge of original species composition. To support the restoration process of a forest preserve on Maryland's Eastern Shore a walking survey was conducted and the results are presented with suggestions for restoration. The survey identified discrepancies with the existing Vegetation Map of Maryland.

INTRODUCTION

Gaps in available information on the spatial distribution of plant species pose a major challenge for regional conservation planning. Suppose a land manager wishes to restore forest land to its pre-settlement condition, but centuries of land clearing and logging have made it difficult to determine the composition of the original forest?

This is the challenge of the Maryland/D.C. chapter of The Nature Conservancy, an organization that hopes to restore upland forests that are part of its Nassawango Creek Preserve on Maryland's Eastern Shore. Most of the upland forest is now managed

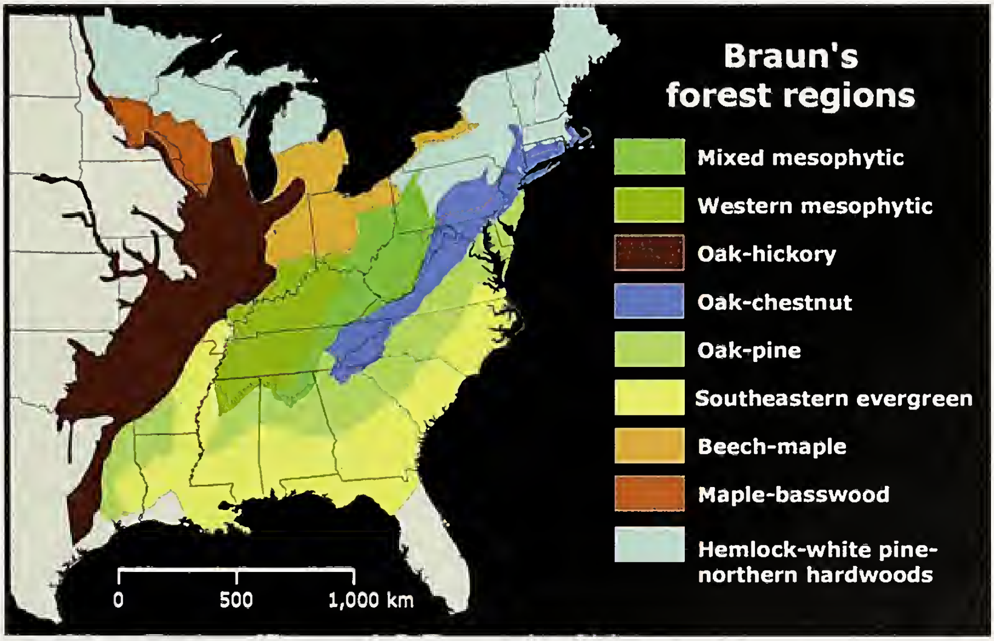

Fig. 1. The nine regions described by Braun (1950), representing original forests of eastern North America (from Dyer, 2006).

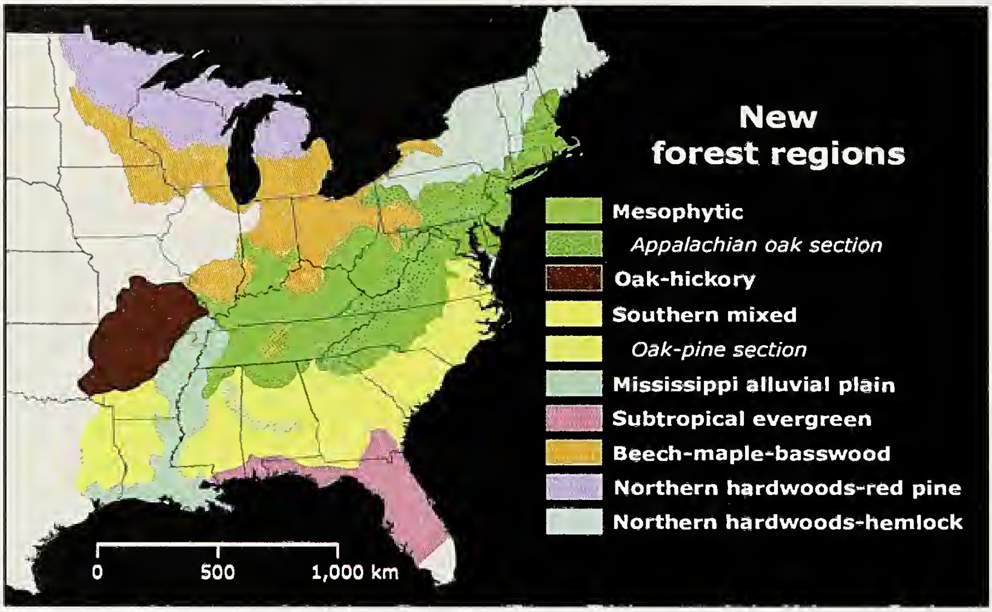

Fig. 2. Forest regions derived from contemporary forest data by Dyer (2006).

for loblolly pine (*Pinus taeda*) production, but sparse descriptions of the forest from 100 years ago indicate that a larger broadleaf component was present historically (Hall 1910, Besley 1916, Harper 1919, see also Maloof, this issue). But what broadleaf species exactly? And how were they distributed? Those questions remain unanswered.

One method of determining historic forest composition is by referring to maps that have already been produced. In 1950, acutely aware of the loss of Eastern original forests, and the concomitant loss of biological information about these forests, ecologist E. Lucy Braun attempted to describe the "original" forest patterns of eastern North America. In the forest regions that she describes, the Eastern Shore is located in the "Oak-pine" region (Fig. 1). In 2006, James Dyer updated Braun's map using data from an extensive network of contemporary forest plots (Fig. 2). He reclassified most of the Eastern Shore into the "Mesophytic" forest region, but also shows a line of transition to "Southern Mixed (oak-pine)" running through the southwestern portion of the peninsula. He notes that the Mesophytic forest is very diverse, and although red maple and white oak are the two most common species, no species assumes canopy dominance across the region.

Although these regional maps are helpful they are not fine-scaled enough to be useful for guiding restoration.

Only one recent statewide survey of Maryland's forests has been published (Brush et al. 1980). Brush et al. (hereafter referred to as "Brush") termed their forest types "associations." Unlike Braun's use of the dominant canopy species to determine forest region, Brush used the presence of characteristic tree species to determine association categories. According to their analysis there were 15 different forest associations in

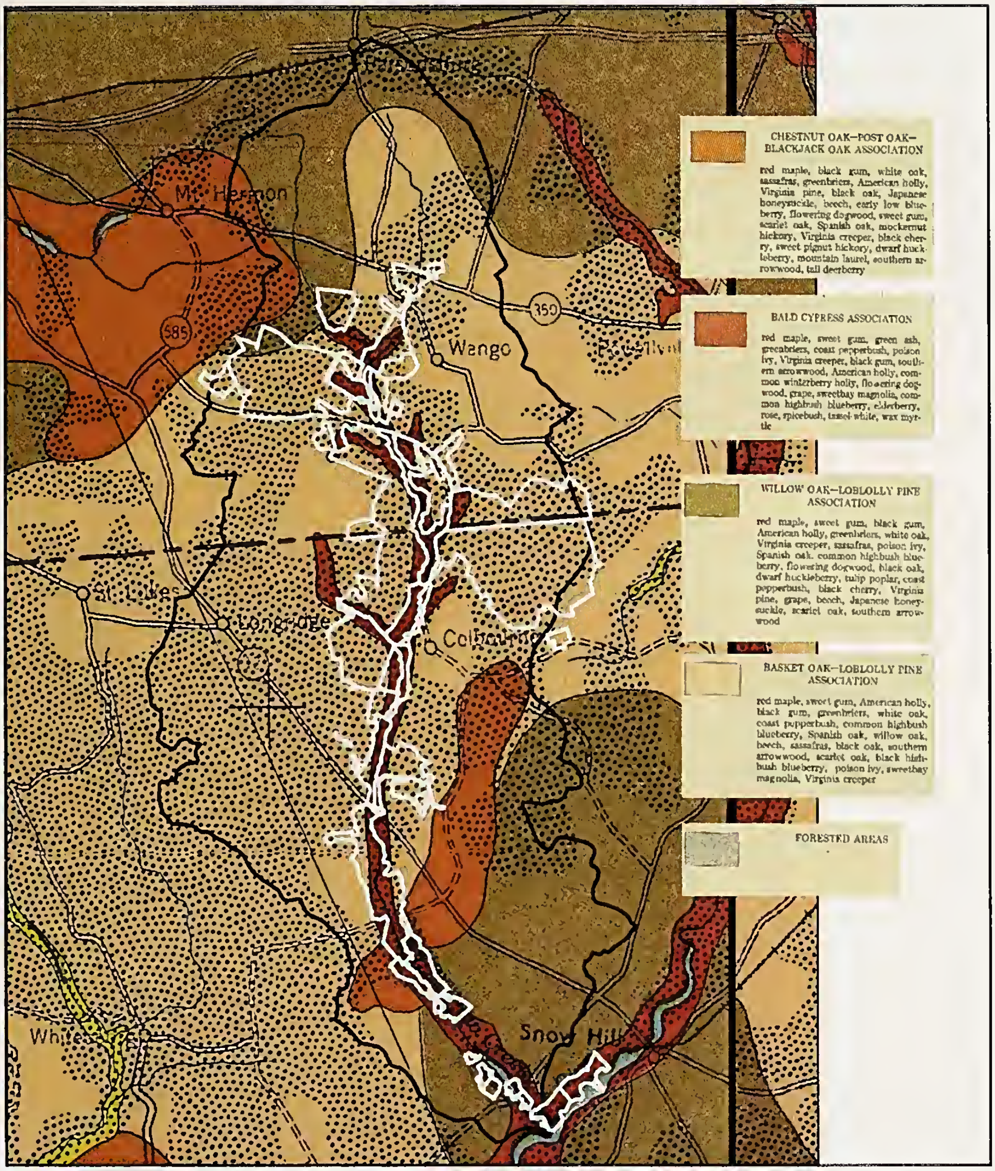

Fig. 3. Portion of vegetation map of Maryland (Brush et al. 1980) showing the outline of the Nassawango watershed (in black) and the Nassawango Creek Preserve (in white).

Maryland, with four of those associations occurring within the Nassawango Creek watershed (Fig. 3).

The Nassawango Creek Preserve occupies a narrow central portion of the watershed. Most of the early land protection activities in the watershed focused on the swamp habitat surrounding the creek and its tributaries; so, consequently, much of the Preserve is in Brush's "Bald Cypress" association, a wetland forest type. The upland forest component of the preserve, of primary interest here, is shown to be largely in the "Basket

Oak- Loblolly Pine" association. But, once again, this information may not be fine-scaled enough for making restoration decisions.

More recently the state has been using a subset of the International Classification of Vegetation (DNR 2004) to classify forest communities in Maryland, but there has been no mapping of the communities on Maryland's Eastern Shore. Also, some of the classifications are problematic, with very little difference between one community type and another. Moving a forest sampling plot just a few meters will frequently change the community designation: a methodological problem that results from using discrete classifications rather than continuous environmental data. Additionally, the classifications relates to current conditions only and tell nothing about what vegetation may have been historically present.

Whether one is describing forest regions, forest associations, or forest communities, the results one gets will depend in part on the scale of observation. For this project, I wanted to determine tree species distribution on a finer scale than was possible for Braun, Dyer, or even Brush. Furthermore, I wanted to use my results as a basis to critique the usefulness of the existing Vegetation Map of Maryland. This finer-scaled examination was accomplished to help guide the restoration of the Nassawango Creek Preserve's upland forests.

Materials and Methods

The Nassawango Creek Preserve is located on Maryland's Eastern Shore (Fig. 4). It is made up of 47 tracts that vary in size, date of acquisition, and management history. The tracts have clearly marked boundary lines and they provide convenient subdivisions for research of this type. Each tract was visited and a walking survey was conducted. The walking survey involved walking the boundary of the tract, making occasional, random transects through the tract, and recording new species as they were observed. Walking and recording were continued until no new species had been recorded for 15 minutes. Species abundance was only noted as present, absent, or rare (if less than three sightings occurred). Using this method, I was able to cover more territory in a shorter amount of time than would have been possible with point surveys. Walking surveys of the entire preserve (approximately 10,000 acres) were completed between 23 June and 6 October 2008.

Results

More than 33 species were observed during the survey. Two species listed in Brush's associations were not observed (blackjack oak and chestnut oak), and 11 species not mentioned by Brush were observed (persimmon, Atlantic white cedar, short-leaf pine, water oak, river birch, hornbeam, hop-hornbeam, horse-sugar, walnut, black willow, and sycamore).

Each species observed was mapped onto the Nassawango Creek Preserve (NCP) tract boundary map (see Figs. 5- 36). In a few instances (described below), species were

lumped together for mapping. If a species was found anywhere in the tract then the whole tract was shaded. Therefore, although our species maps are a finer scale than any previously produced, they are not finer grained than the tract size. Species described as "not present" should more properly be described as "not found" because it is possible that individuals of a species were missed on the walking survey.

Below I describe the distribution of each species and compare that to the associations mapped by Brush. Table 1 is a summary for comparing the results of the two studies.

Red maple, black gum, sweet gum, and holly (Figs. 5-8) are ubiquitous in the Preserve. Likewise, Brush listed them in every association in the Nassawango watershed. Brush lists sassafras as occurring in every association except the Bald Cypress Association. I found sassafras to be near-ubiquitous, occurring even in tracts completely within the area mapped as Bald Cypress Association (Fig. 9). Brush does not mention persimmon, but I found it to be another near-ubiquitous tree with a distribution similar to sassafras (Fig. 10). Brush lists swamp magnolia as occurring in only the Basket Oak–Loblolly Pine Association and the Bald Cypress Association. Since every one of the NCP tracts contains one, or both, of these associations, my results of the near-ubiquitous presence of swamp magnolia in the Preserve coincides with Brush (Fig. 11). It would be interesting to examine areas entirely within the Chestnut Oak-Post Oak-Blackjack Oak Association and the Willow-Oak Loblolly Pine Association to see if swamp magnolia exists there also. If it does not, this would confirm Brush's results.

Brush observed wild cherry to be in the exact opposite associations from swamp magnolia, yet my data shows it to be throughout the same range (Fig. 12). Cherry trees were not as common as sassafras and swamp magnolia, and frequently occurred only on the margins of the tracts where birds might drop seeds. I found dogwood to be sparsely distributed throughout the length of the preserve (Fig. 13). It appears to be concentrated in the Bald Cypress Association, as Brush predicts, except for its occurrence in a large northwestern tract that enters the Willow Oak -Loblolly Pine Association where dogwood is predicted to occur as well.

Bald cypress occurs in most of the tracts of the Preserve (Fig. 14). According to Brush's scheme of associations, any area containing bald cypress would be considered a Bald Cypress Association, yet some tracts entirely outside of this mapped association contain bald cypress. Brush lists ash as occurring only in the Bald Cypress Association. My results concur. In fact, I find ash to be a better predictor of the mapped Bald Cypress Association than bald cypress is (Fig. 15).

Atlantic white cedar appears to have a restricted range toward the north-center part of the watershed (Fig. 16), but, like many of these species, it is difficult to say what the historic range was, as it has been logged out of many areas and it does not reproduce without fire. Brush does not mention observing Atlantic white cedar.

Brush lists loblolly pine as occurring in only two out of the four associations, but I found loblolly pine growing throughout the preserve (Fig. 17). Although many of

the pines were planted, or grew as a result of recent clearing, mature loblolly pines were also seen growing in "Bald Cypress" areas. Unlike Brush, I consider loblolly pine (along with red maple, black gum, sweet gum, and holly) a ubiquitous species throughout the watershed. According to Brush's associations, Virginia pine should only be found in the extreme northwest part of the preserve and the southern section. My results do not concur with Brush, as I found Virginia pine lightly distributed throughout the preserve, with the exception of the extreme southern portion along the Pocomoke River (Fig. 18). Short-leaf pine was not mentioned by Brush. I found it to be even more lightly distributed than Virginia pine (Fig. 19).

Brush calls southern red oak (*Quercus falcata*) "Spanish Oak" and lists it as occurring in every association except bald cypress. I found it to be throughout the Preserve, including in areas containing bald cypress, with the exception of the portion of the preserve along the Pocomoke River (not technically in the Nassawango watershed; Fig. 20). I included cherry-bark oak (*Quercus pagoda*) here, as Brown and Brown (1972 [reprinted 1999]) considered it a variety of *Q. falcata*. Brush lists blackjack oak (*Q. marilandica*) as one of the characteristic species in an association; however, I did not observe it in my survey. There is a variety of *Q. falcata* that resembles *Q. marilandica* (a herbarium specimen is on file at Salisbury University) and it may be that Brush's team confused the two. Water oak is another widespread species (with the same distribution as s. red oak; Fig. 21). Strangely Brush does not mention this species. It is possible that she identified this species as blackjack oak (which I did not find). Oaks are notoriously difficult to identify.

White oak is another well-distributed species throughout the preserve, though not as common as s. red oak and water oak (Fig. 22). Brush lists it as occurring in every association except bald cypress. Willow oak is one of Brush's characteristic species for the Willow Oak-Loblolly Pine Association. I found willow oak to be even more lightly distributed throughout the preserve than the other aforementioned oaks (s. red, water, white; Fig. 23). Its distribution did not seem particularly noteworthy, and in tracts where it did occur, loblolly pine was present too, making those tracts technically Willow Oak-Loblolly Pine Associations, although they were not mapped as such by Brush. According to Brush's scheme willow oak and post oak are not found in the same associations, and both are considered characteristic species in the associations where they occur. My tract data contradict this, and also show post oak occurring in the Basket Oak- Loblolly Pine and Bald Cypress associations where it is not predicted to be (Fig. 24). I found post oak common in the mid-northern tracts, disappearing as one moves south, and then appearing again in a particularly oak-rich section in the mid-south portion of the Preserve (Foster tract).

Swamp chestnut oak (*Quercus michauxii*) is called "Basket Oak" by Brush, and they list it as a characteristic species only occurring in the Basket Oak- Loblolly Pine Association. I found it to have a distribution somewhat similar to post oak, although according to Brush the two should not occur in the same associations (Fig. 25). Black

oak, n. red oak, scarlet oak, pin oak, and others are the less-common oaks in this watershed (Fig. 26). They can sometimes be difficult to distinguish from the ground on a walking survey, with no acorns or leaves at hand. Additionally these oaks are known to hybridize with the other oaks and with each other, making identification even more difficult. These four oaks were lumped together for the purpose of this survey. The black oak was listed by Brush in all associations except the Bald Cypress, and she did not mention the others. One interesting note about this oak complex is that it roughly parallels the post oak–swamp chestnut oak pattern, with the addition of occurring in the extreme southern portion where those oaks did not exist.

The hickories have a distribution similar to the post oak and the swamp chestnut oak, occurring primarily in the northern part of the preserve (Fig. 27). Brush puts hickory only in the Chestnut Oak–Post Oak–Blackjack Oak Association, but as with the post oak distribution, my data conflicts with her map.

I found tulip-poplar to be rare in the preserve, occurring only in the extreme south near the tidal areas (Fig. 28). Beech was also surprisingly uncommon in the preserve, occurring primarily in the southern section with the exception of a few scattered populations in the north (Fig. 29).

River birch was not mentioned by Brush for any of these associations (although she did mention it as a component of other associations in the state). I found river birch to have the most distinctive distribution of any of the trees (Fig. 30). It did not

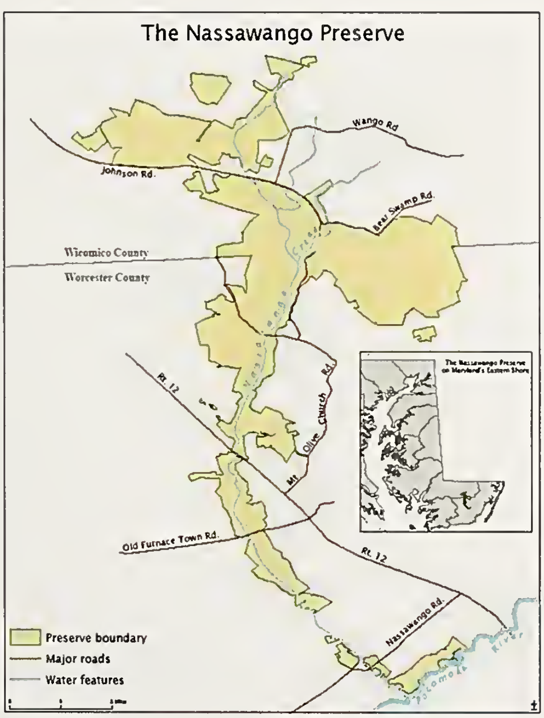

Fig. 4. Location of the Nassawango Creek Preserve on Maryland's Eastern Shore.

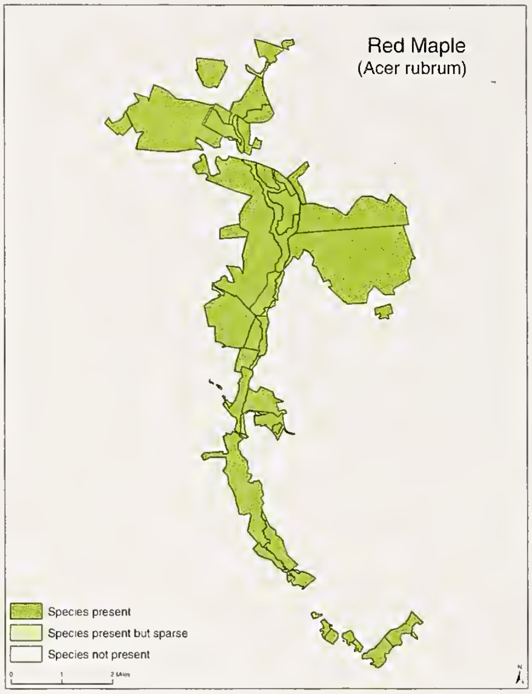

Fig. 5. Red Maple

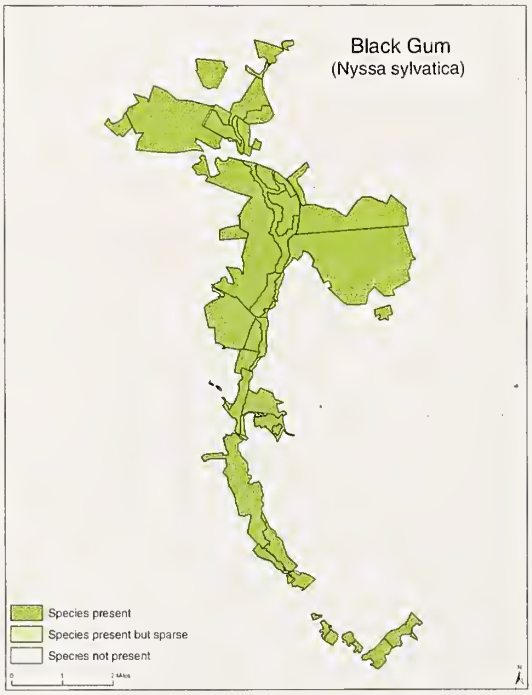

Fig.6. Black Gum

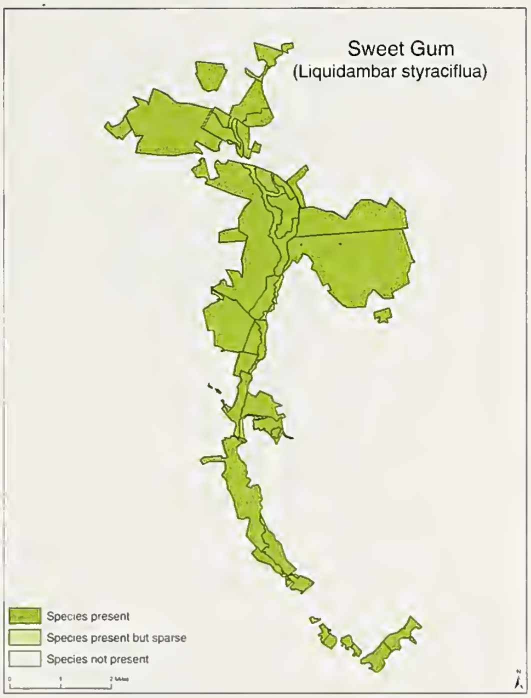

Fig.7. Sweet Gum

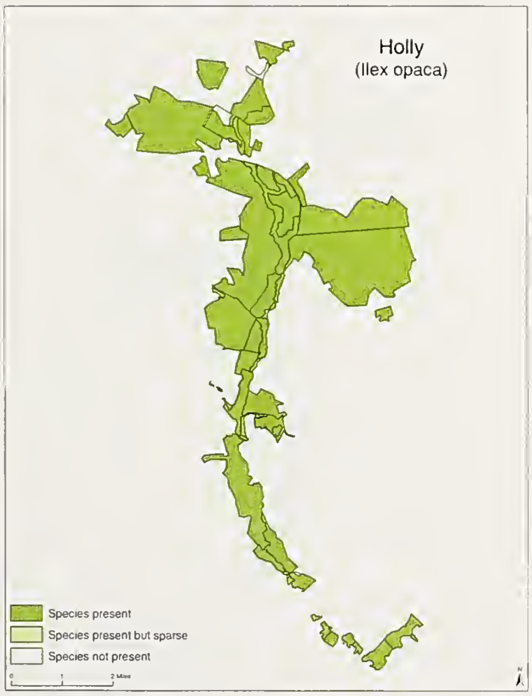

Fig.8. Holly

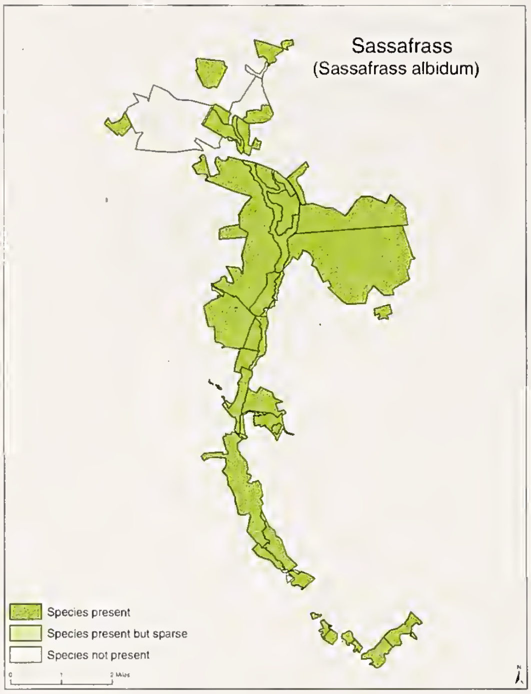

Fig.9. Sassafrass

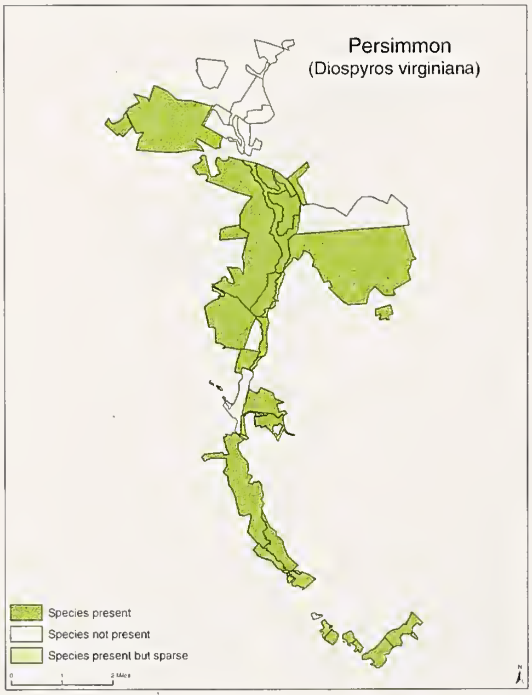

Fig.10. Persimmon

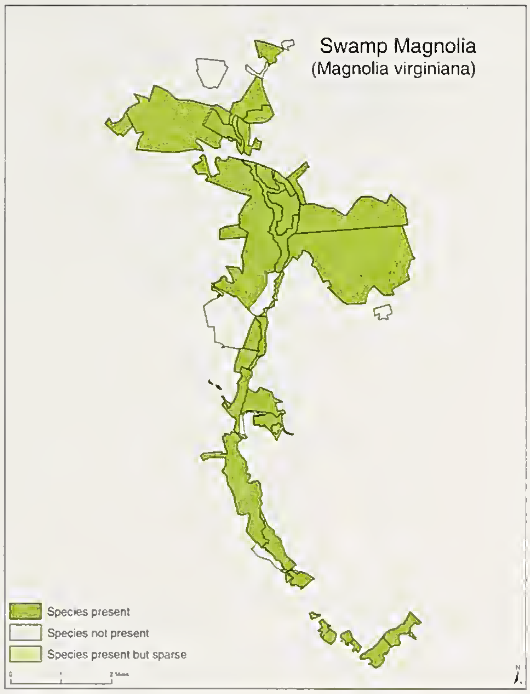

Fig.11. Swamp Magnolia

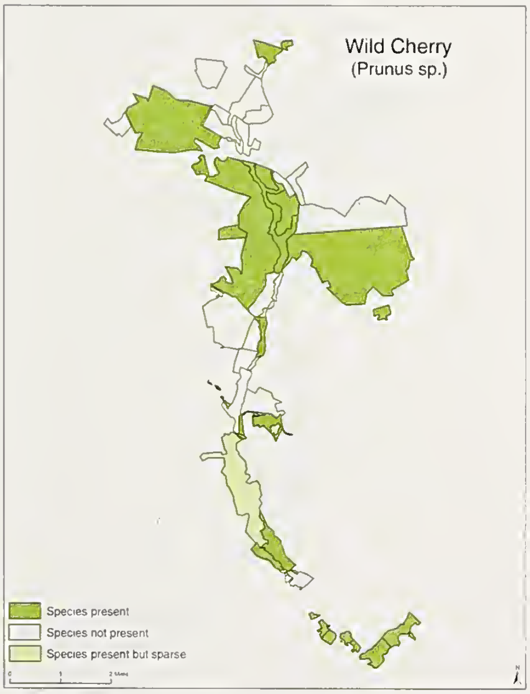

Fig.12. Wild Cherry

Fig.13. Dogwood

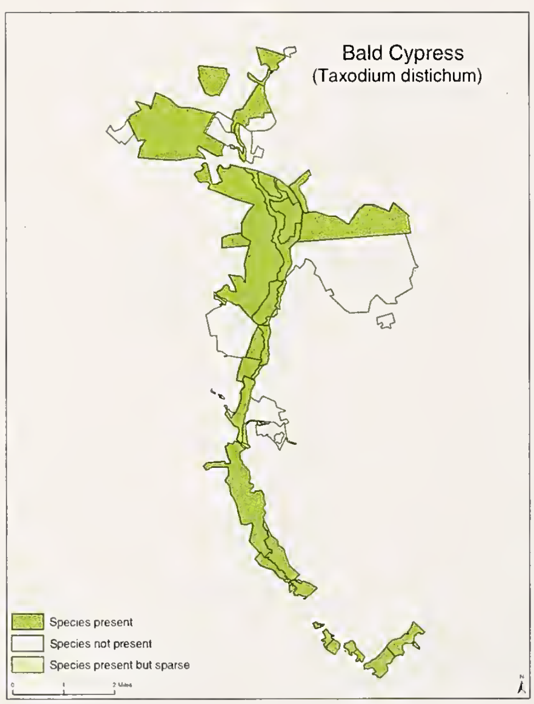

Fig.14. Bald Cypress

Fig.15. Ash

Fig.16. White Cedar

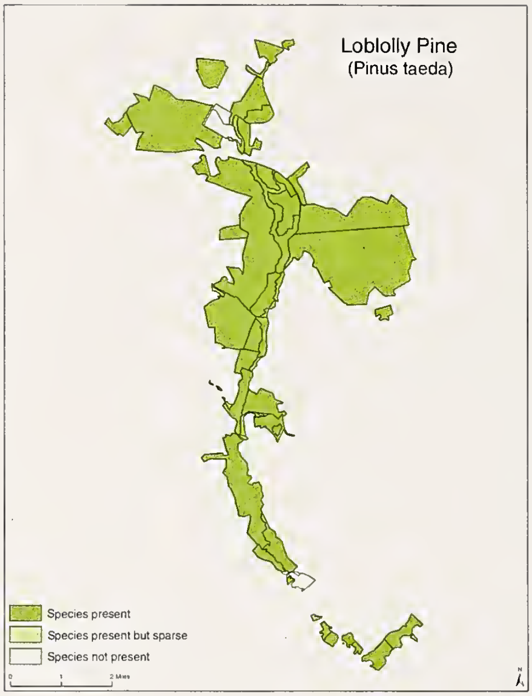

Fig.17. Loblolly Pine

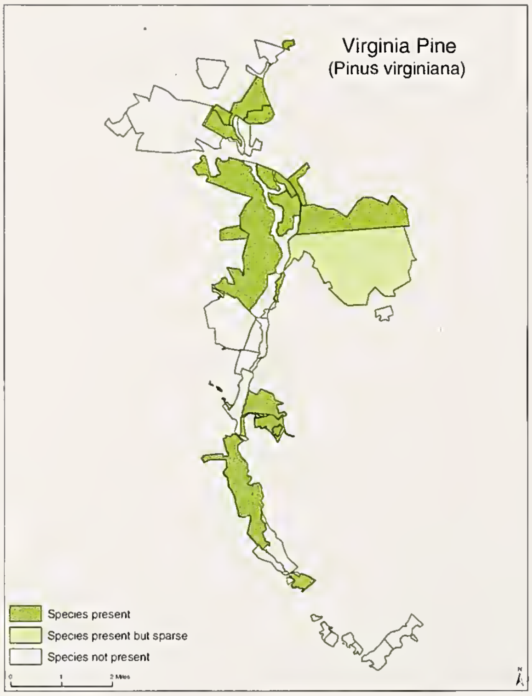

Fig.18. Virginia Pine

Fig.19. Short Leaf Pine

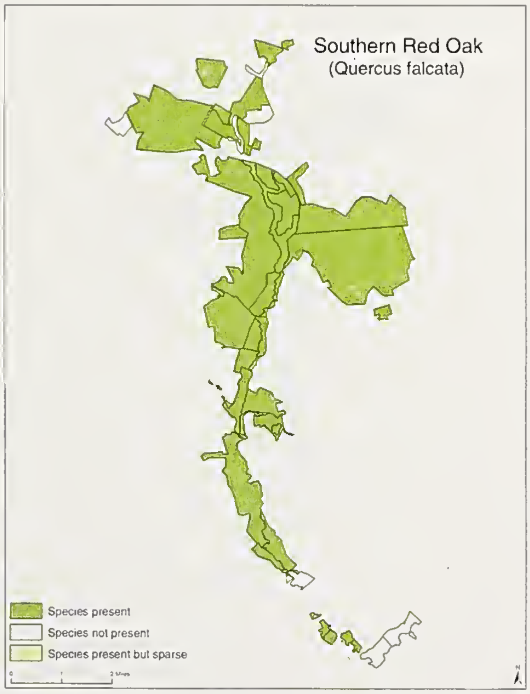

Fig.20. Southern Red Oak

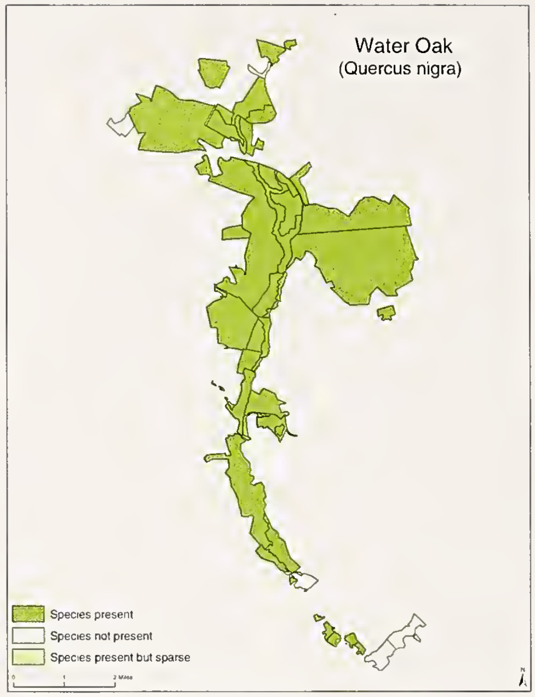

Fig.21 Water Oak

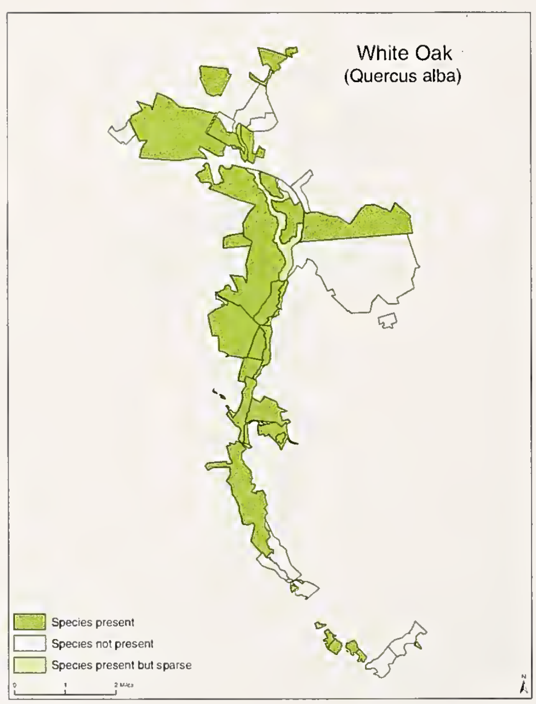

Fig.22. White Oak

Fig.23. Willow Oak

Fig.24. Post Oak

Fig.25. Swamp Chestnut Oak

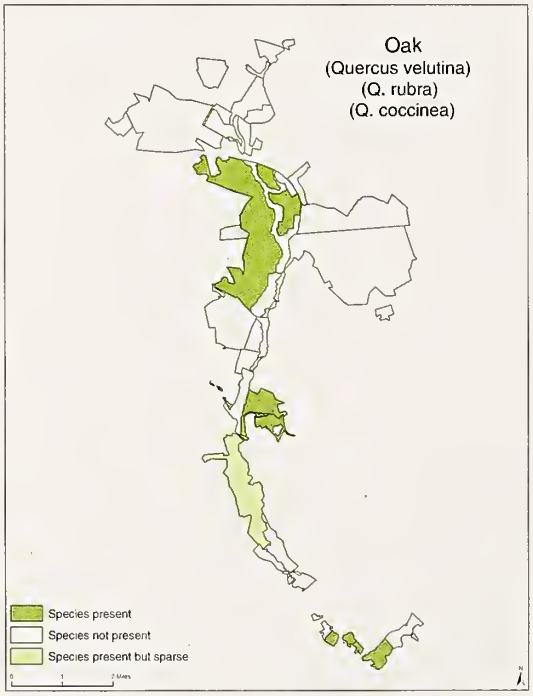

Fig.26. Other Oaks

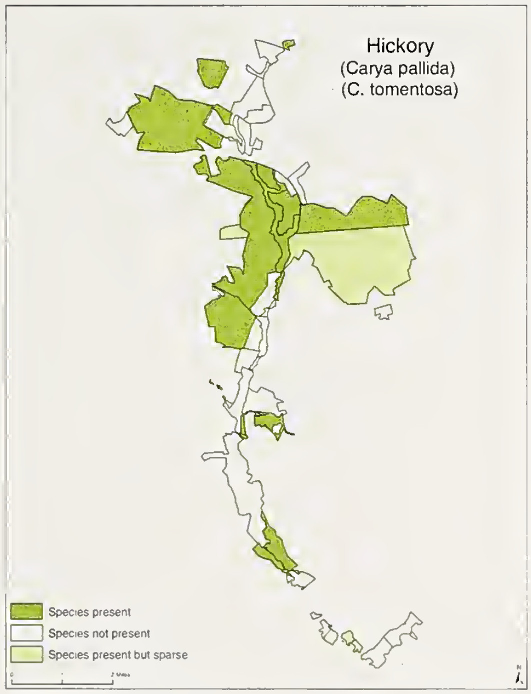

Fig.27. Hickory

Fig.28. Tulip-poplar

Fig.29. Beech

Fig.30. River Birch

Fig.31. Hornbeam

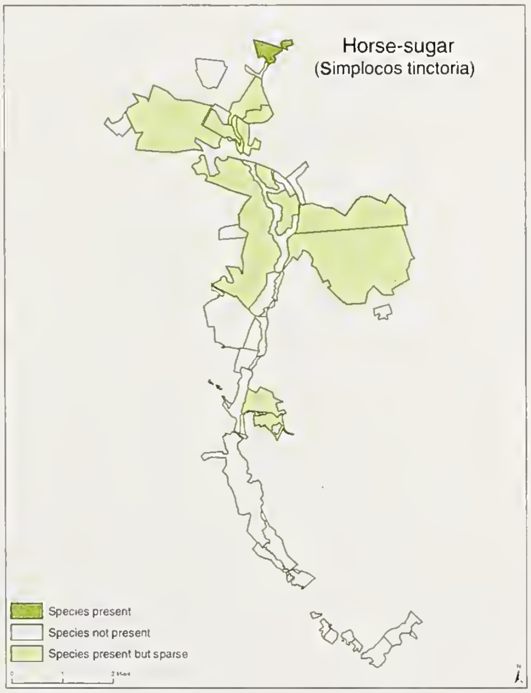

Fig.32. Horse-sugar

Fig.33. Hop-Hornbeam

Fig.34. Walnut

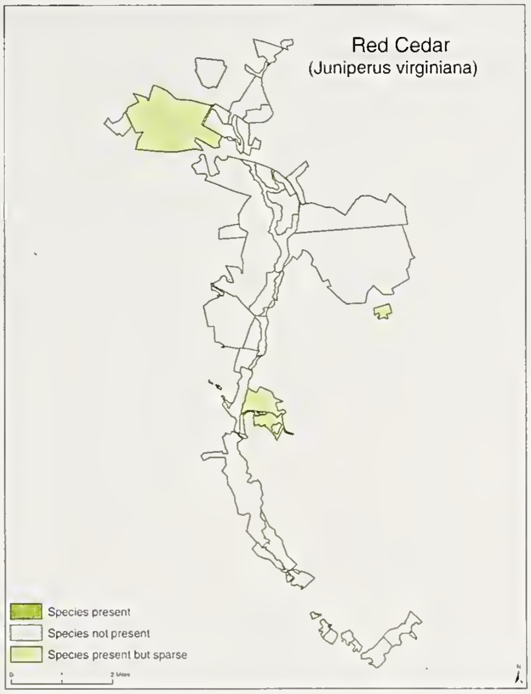

Fig.35. Red Cedar

Fig.36. Sycamore

occur in the north or the south of the preserve, but there was a large population of it through the center section. Hornbeam, not mentioned by Brush in these associations, also had a very distinctive distribution, occurring primarily in the southern areas (Fig. 31). Horse-sugar, not mentioned by Brush, had almost the opposite distribution of hornbeam (Fig. 32).

Hop-hornbeam was so lightly distributed that I consider it a rare species (Fig. 33). Although it occurs throughout almost the entire eastern United States, it tends to be very sparsely distributed where it does occur (Iverson et al. 1999). Walnut, not mentioned by Brush for these associations, also had a very sparse and scattered population (Fig. 34). Walnut was generally found in association with an old home site, and for that reason I do not consider it to be a native species in the watershed.

Red cedar was mentioned by Brush as occurring here only in the Chestnut Oak-Post Oak-Blackjack Oak Association. That association would only be found in a small section of tracts in the mid-south area. I did not find red cedar in the areas predicted by Brush, but found it scattered, sparsely in other areas where it was not predicted to be (Fig. 35). Like cherry, the red cedars were primarily found along road edges where they were likely spread by birds. Although red cedar occurs naturally in other watersheds in the region, I do not consider it a typical native species to this watershed.

Black willow, not mentioned in this area by Brush, was found in one roadside location in the south. Sycamore, not mentioned by Brush, was uncommon the Preserve (Fig. 36). Where it did occur, it seemed to be naturalized, but it could be in the watershed as a result of a historic introduction. Its distribution being somewhat similar to walnut would also point toward this possibility. Furthermore, Harper (1919) lists sycamore and walnut as absent in this area.

Discussion

This survey identified discrepancies with the existing Vegetation Map of Maryland (Brush et al. 1980). It also revealed fine-scale vegetation patterns (such as that of the river birch) that may lead to future ecological research. A wider range of species was found during these walking surveys than was noted in either the pollen study or the witness tree records for this region (Maloof, this volume).

Although tract boundaries are often arbitrary relative to physical and biological features that determine plant communities, and hence they may not be an ideal way of partitioning the landscape for a survey, in this instance, the tracts proved to be practical and convenient subdivisions. Further subdivisions within the larger tracts may prove useful for future research.

Species data collected in this manner may also prove useful in future mapping of community types. A stack of species-distribution maps can be subjected to analysis (such as principal-component analysis) to develop community-level models. Less common species may prove to be especially useful in these models (Ferrier and Guisan 2006).

Restoration of the forestlands in the Nassawango Creek Preserve should take into account the position of the tract within the preserve. All tracts, especially when young, should be expected to contain the ubiquitous species: red maple, black gum, sweet gum, holly, sassafras, persimmon, swamp magnolia, southern red oak, water oak, and loblolly pine. I expect that these species would return naturally and no special effort would be necessary to reintroduce them. Wetter areas, where bald cypress occurs, should contain the aforementioned species and also ash, and Atlantic white cedar toward the north. These may need to be protected or reintroduced. Tracts where slightly less common species occur, such as short-leaf pine and oaks (besides n. red, water, and white), should be given special attention to encourage these species. In the north, the horse-sugar tracts should be managed to preserve this unusual species. In the southern tidal sections, the less-common (for this area) tulip-poplar, beech, hornbeam complex should be considered in restoration planning. In the center section the river birch, hop-hornbeam area should be preserved.

A second look at Brush's map (Fig. 3) confirms that none of these important restoration considerations could be discerned from that map. Likewise, the Maryland Community Classification scheme (DNR 2004) would have placed all of the uplands here in either the Loblolly Pine Forest Alliance or the Loblolly Pine (White Oak, S. Red Oak, Post Oak) Forest Alliance with no further information on species distribution. The finer grained approach used here has resulted in useful new information to guide the restoration of the Maryland Conservancy's Nassawango Creek Preserve.

Acknowledgements

This work was supported by a grant from the Nature Conservancy. Adrianne Witkowski assisted with support from a Salisbury University Henson School Undergraduate Research Award. Andrew Keicher produced the species distribution maps and Michael Ross Allen produced the maps of the Nassawango Creek Preserve. Thanks to all of these wonderful students.

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Maloof, J., this volume. Native forests in the Nassawango Creek Watershed and surrounding areas: piecing together the past and the present.

CHARACTERIZATION OF NATIVE FORESTS IN THE NASSAWANGO WATERSHED: PHYSICAL FEATURES

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ABSTRACT

Forest restoration objectives often include optimizing plant species diversity. Managing for spatial heterogeneity, including coarse woody debris and fine-scale topographic variability, can enhance habitat heterogeneity. We investigated the variability in these features within forest communities representing earlier and later stages of succession in an attempt to develop a target for upland forest restoration within the Nassawango Creek Watershed on the Eastern Shore of Maryland. Relatively little microtopographic variability was found in either younger or older systems, and no differences were discerned in abundance of coarse woody debris, soil chemical constituents, or organic content. The importance of microtopographic variability in restoration of upland forests and in the context of historical community structure is discussed.

INTRODUCTION

Nassawango Creek is the largest tributary of the Pocomoke River, a relatively undeveloped river on Maryland's Eastern Shore. The Nassawango Creek Watershed contains a mosaic of forests in various successional stages. Extensive wetland and upland communities of prime ecological significance (including a Wetland of Special State Concern that is designated as a Maryland Natural Heritage Area) provide habitat for rare plant and animal species, including 88 listed as threatened, endangered, or of special conservation interest by Maryland, and six globally rare species. Forested wetland communities include century-old *Taxodium distichum* (baldcypress) in association with *Nyssa sylvatica* (black gum). The relatively undisturbed nature of these swamps was important in their acquisition and conservation by The Nature Conservancy, whose Nassawango Creek Preserve now consists of 10,000 acres (almost 1/4 of the watershed area) and represents the Conservancy's largest holding in Maryland (TNC 1999).

To enhance Nassawango Creek forest biodiversity, the Conservancy has begun developing a long-term management plan for about 6,000 acres of upland forest in the watershed, most of which was used in the recent past to grow loblolly pines (Pinus taeda) for commercial timber and pulp production. The management goal for these forests includes a comprehensive and carefully monitored native forest restoration program.

To further this goal, a target for native upland forest composition and structure is

required. Such a target includes plant species composition as derived from pollen records, early eye-witness reports, botanical collections, historic land survey records, species distribution patterns, present-day surveys, and old-growth remnants. Characterization of a target forest physiognomy should follow the concept described by Landres et al. (1999) that "past conditions and processes provide context and guidance for managing ecological systems today."

Present-day surveys are limited by the dearth of representative old-growth forests. Forests throughout the Nassawango Creek watershed, as with most of the eastern seaboard, have been substantially altered by widespread clearing and ditching for silviculture and agriculture, by extirpation of many large mammalian predators, and by changes in the numbers of other animal species, including white-tailed deer (substantially increased) and beavers (greatly decreased). These changes, and fragmentation of forests by development, alter their physical and their biological characteristics. Both ditching and beaver removal can have major impacts on hydrology and have probably altered the relative degree of water availability to many forests, likely converting an extensive region from swamp to upland, with associated changes in species composition.

A restoration target for the forest community, with the combination of methods noted above, is presented in the companion paper "Native Forests in the Nassawango Creek Watershed and Surrounding Areas: Piecing Together the Past and the Present" (Maloof 2011). However, forest restoration is a complex undertaking that extends beyond the establishment of tree species. As Kuuluvainen et al. (2002) explain, forest restoration endeavors to bring together species, physical structures, and long-term dynamic processes. In addition to plant community composition, the key physical features underlying forest communities are also important in establishing a restoration target.

The Maryland Department of Natural Resources' "Old Growth Committee" listed five features characterizing old-growth forests, including abundant shade-tolerant species; randomly-distributed canopy gaps; extensive structural diversity within the living community; prevalence of dead branches, snags, and coarse woody debris; and pit and mound topography (soil conditions permitting). Many of these features are present in forests as a result of disturbance. Generally, wide-scale disturbance diminishes over the course of temperate forest secondary succession (Huston and Smith 1987, Grime 1979), and plant competitive interactions become more important. However, fine-scale disturbance, in the form of stochastic processes producing density-independent mortality, is present through the life of a forest (e.g. Boerner 2006), and these processes, combined with "natural" mortality, lead to the creation of canopy gaps and pit and mound formations, both of which create spatial variability in the community composition. Treefall-generated canopy gaps alter the light and moisture regime, facilitating colonization by earlier successional stage species and producing landscape patches that result in an overall increase in species diversity. Uprooting of trees adds pit and mound features to this variability. The resulting heterogeneity of edaphic conditions increases species diversity, as microenvironments associated with different species' physiological

tolerances are juxtaposed, creating patterns of both physical features and plant distribution (Beatty 1984, Peterson et al. 1990). Such variability has been documented for upland forests from the Great Smoky Mountains (e.g. Hicks 1980) to New England (Beatty 1991). Titus (1990) found that microsite elevation was the most strongly correlated of several different environmental factors with seedling distribution in a Florida hardwood swamp.

Thus, an important physical feature in a mature forest may be microtopographic variation, generally defined as variability of substrate and objects at the scale of the dominant vegetation in systems dominated by macrophytes (Huenneke and Sharitz 1986, Kleb 1999). Microtopography both controls and is determined by community composition and long-term processes. The importance of establishing microtopographic variability as part of the restoration of upland forests (Kuuluvainen et al. 2002) and of forested wetland ecosystems has also been documented (Huenneke and Shartiz 1986, Bledsoe and Shear 2000).

The primary objective of this study was to characterize the microtopographic variability of a number of upland forests in the Pocomoke River Watershed and to examine whether there was a difference in the extent of this feature between older and younger forests. Ultimately, we endeavored to establish whether this degree of variability could or should be used as a target physical characteristic in restoration of upland forests. We also characterized coarse woody debris abundance, litter and duff depth, and soil texture and chemical features for the same sites.

Methods

Our sampling sites included seven forest stands in the Pocomoke Watershed (Fig. 1) that were identified as being older and younger stands paired with six of these sites (one site, 4A, did not have a younger pair). Plots were selected as described by Maloof (2011) and judged to be older or younger by a visual inspection of the area, which included considerations of tree size, species, spacing, and presence of stumps and dead wood. Younger plots were located within 500 m. of the older plot, in a forest that appeared to have been cleared more recently, yet which would have likely contained the same forest type historically. The relative ages of the pairs varied, such that the younger plot from one pair might be older than the older plot from another pair; however, for consistency, younger and older plots were grouped by their relative position within the pair. We did not sample Maloof's sites 2A and B, due to their unusually steep slopes, which were unworkable with our microtopographic analysis.

A central location in each stand was identified as the plot center, flagged and recorded by GPS. This center anchored a circular transect for microtopographic measurements. It was also the center for two randomly-oriented, perpendicular 50 m. linear transects for coarse woody debris (CWD) sampling, which was conducted following the protocol of the British Columbia Ministry of Environment, Lands and Parks (1998).

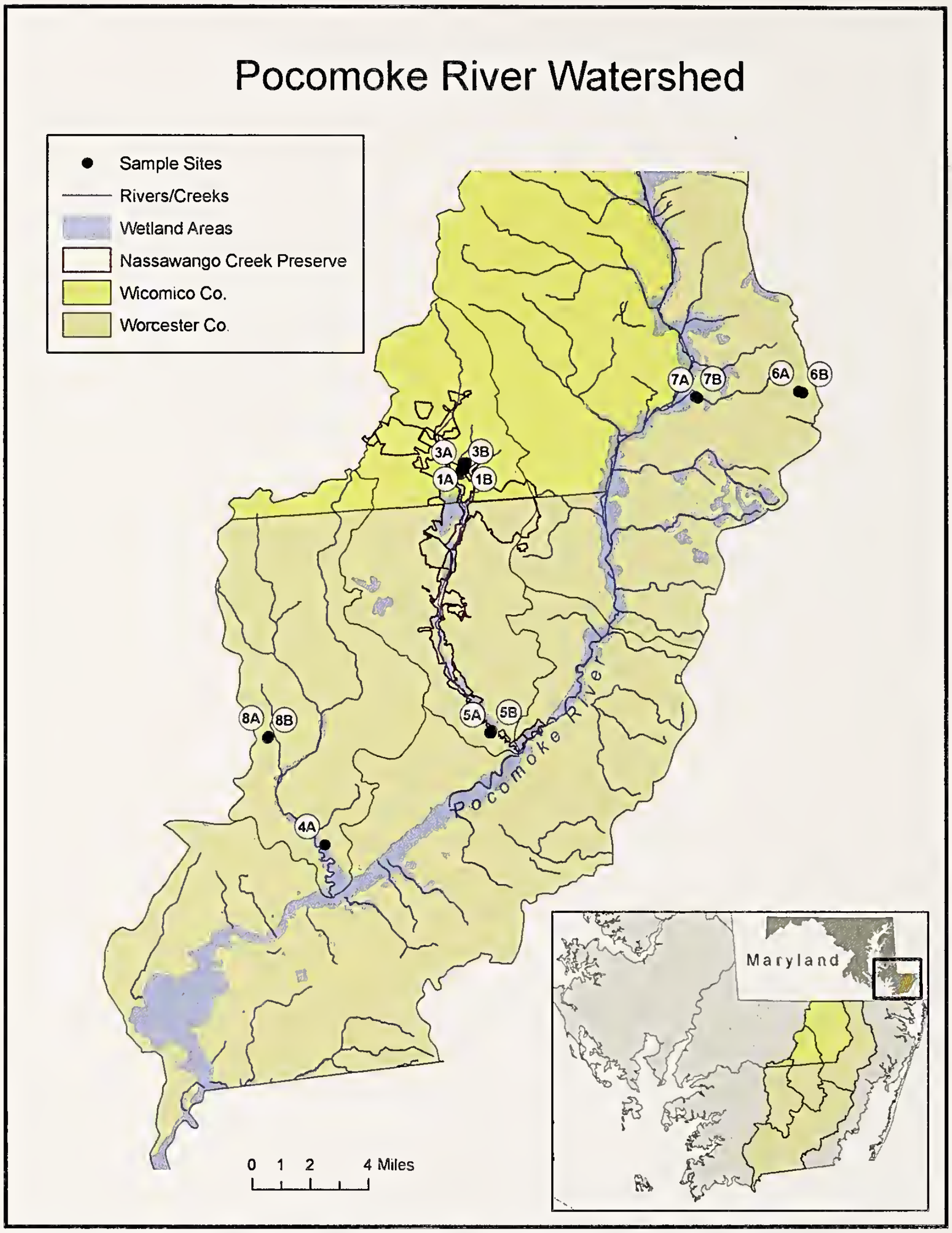

Fig. 1. Pocomoke River Watershed (Maryland portion) with study plot locations.

CWD was defined as any branch or trunk larger than 4 cm. in diameter at its point of intersection with the transect. Diameter at point of intersection and length of fragment were measured, and decay class was determined. Where possible, the species of tree was identified.

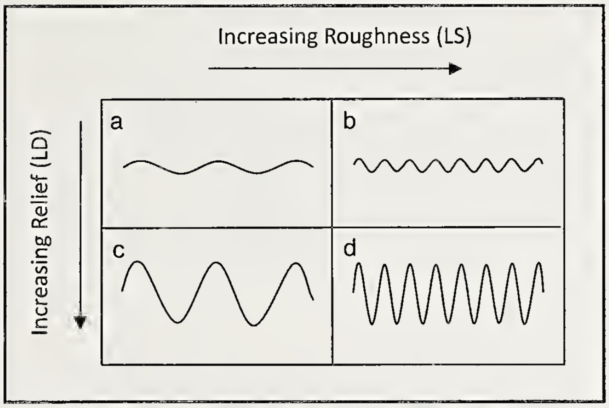

Fig. 2. Characterization of microtopographic features of roughness and relief, after Moser et al. (2007). Surface profiles are depicted in cross-section, with increasing roughness producing an increase in limiting slope (LS), and increasing relief resulting in increased limiting elevation difference (LD). An earlier successional community might be represented by b, and a mature forest by c.

Microtopographic elevation was determined using a Topcon GTS-229 Total Station. Circular transects of 10m radius were used with 72 sampling points (every 5°). Due to limitations of the surveying device, we were unable to measure elevation in three of the more densely vegetated younger forests (1B, 6B, and 8B).

We quantified the elevation results using the geostatistical technique developed by Linden and Van Doren (1986) as described in Moser et al. (2007). We adapted this method, previously applied only to herbaceous systems, to the scale of the forest vegetation, increasing the circular transect to 10 m. diameter. Microtopographic variability was quantified using indices of roughness and relief, with limiting slope (LS) representing roughness, and limiting elevation difference (LD) representing relief (Fig. 2). These values are derived from the variogram of change in elevation (ΔZ_h) as a function of horizontal interval of measurement (X_h), or lag distance, using linear regression of $1/\Delta Z_h$ as a function of $1/X_h$:

$$1/\Delta Zh = b(1 - X_h) + a$$

LS and LD were established from the fitted line parameters as $1/b$ and $1/a$ respectively.

For soil chemical analysis, soil cores were collected at three points at 120° intervals along each transect circle, from 2 depths (0-30 cm., 30-60 cm.). The three samples were pooled for each depth. The soils were analyzed by Brookside Laboratories (New Knoxville, OH) for pH, organic content, estimated N release, P and S; the cations Ca, Mg, K, and Na; and trace metals Fe, Mn, Zn, Cu, and Al. We also performed a rough texture analysis in the field.

At the same 120° interval transect positions, we measured the depth of the Oi horizon (old terminology O1; Soil Science Society of America 1987), or litter, of the combined Oa and Oe horizons (old terminology O2, or duff), and of the A1 horizon (characterized by color and contrast, using a Munsell soil color chart).

Results

Microtopography

In general, microtopographic variability was relatively modest (Fig. 3). The geostatistical quantification of microtopography produced limiting slope (LS; roughness index) values between 0.19 and 0.03 for the older forests, and from 0.11 to 0.34 for the younger. Limiting elevation difference (LD; relief index) values ranged from 24.3 to 6.4 for the older forests, and from 9.0 to 7.0 for the younger. For comparison, Moser et al. (2006) found an almost identical range of LS values (between 0.03 and 0.34) and LD values (between 6.4 and 24.3) for a herbaceous wetland, where one would expect a far finer scale of variability consistent with the size of the vegetation.

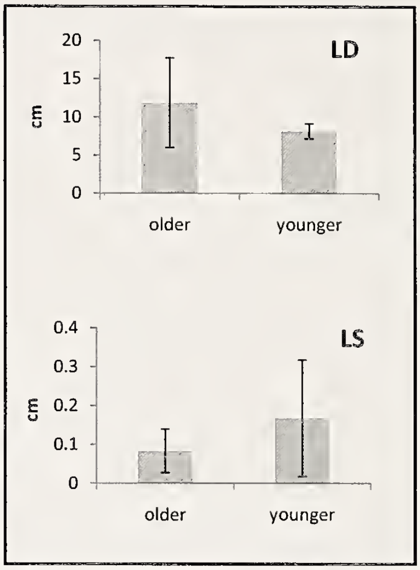

Fig. 3. Forest elevation profiles for all sites surveyed. Older plots are designated A, younger plots B. Data are slope-corrected. Off-scale value for 7B is 80.6 cm., and for 5A is -31.8 cm.

There was no significant difference between the two classifications of forest for either of the microtopographic indices (Fig. 4). Treefall pit and mound systems were rarely observed, and only one was intersected by the circular transect (site 7B, Fig. 3). The magnitude of variability at this point, 80.6 cm., far exceeded that observed in the other transects (the closest was a 56 cm. elevation extent in the site 6A transect). The highest combined roughness and relief index values were found for site 6A, which was perhaps the oldest site sampled. Although our sample sizes were too small to disclose a difference, there is a suggestion of a trend toward lower LD and higher LS for the older plots. This would be consistent with a more coarse-scale, higher magnitude microtopographic variability characteristic of older forests, as illustrated in Fig. 2c.

Soils

Soil organic matter, as expected, diminished greatly with depth (t-test: $p<0.001$; Fig. 5). Soil chemical constituents did not differ significantly between the older and younger forest groups (Table 1). Most studies of forest soils on the Delmarva Peninsula focus on wetlands, and upland soil nutrient data are generally derived from landscapes that have been tilled and fertilized. Concentrations of macro- and micro-nutrients were generally very close to those measured in a study of undisturbed graveyard soils (many forested) within the same region of the Delmarva Peninsula (C. Briand, S. Geleta, B. Zaprowski and M. Folkoff, Salisbury University, unpublished).

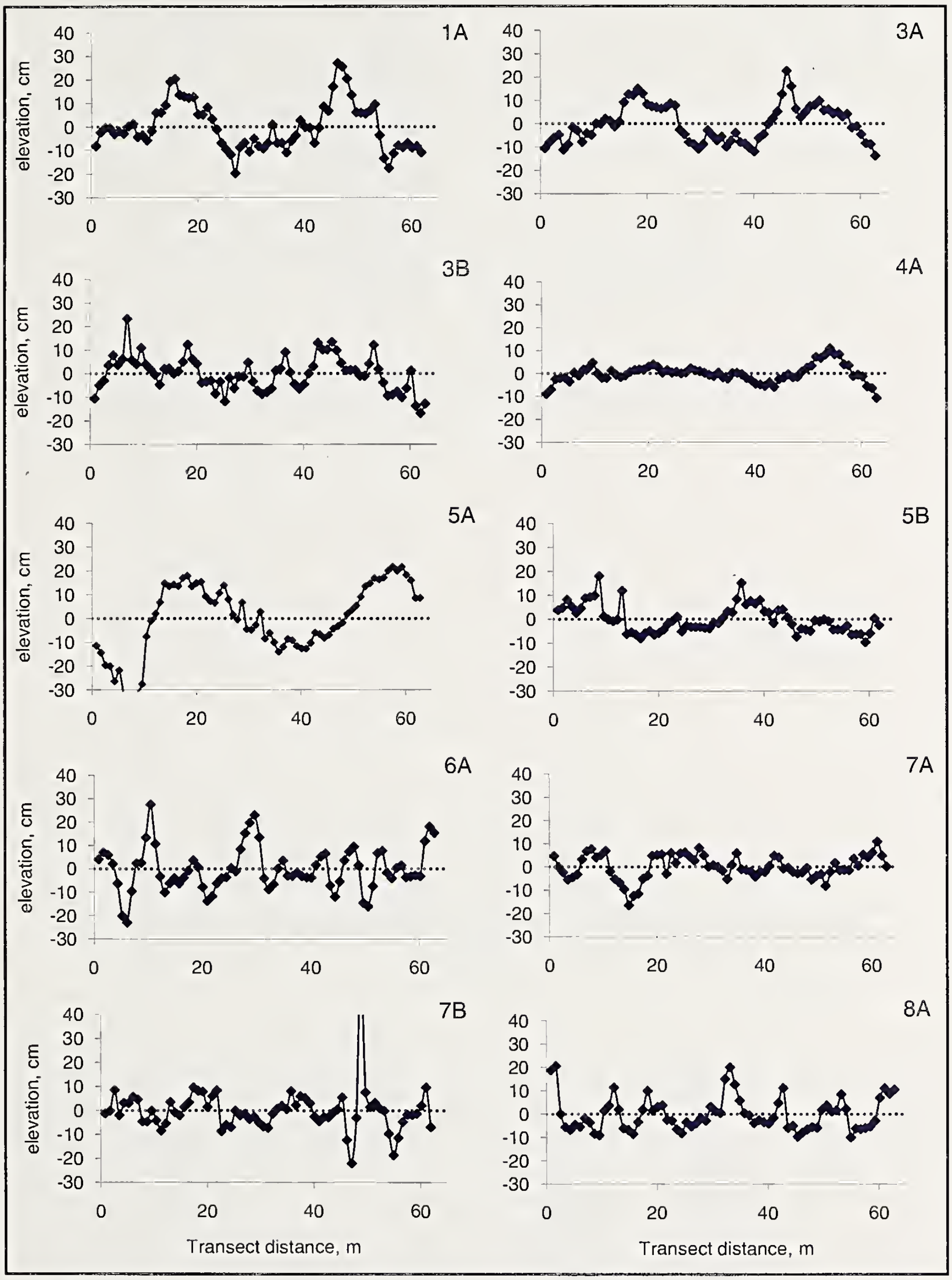

Fig. 4. Limiting elevation difference (LD) and limiting slope (LS) means for the two forest types; error bars are ± 1 s.e. Older: n=7; younger: n=3.

		OLDER		YOUNGER	
Depth, cm.		0-30	30-60	0-30	30-60
	TEC	17.5	10.2	18.4	9.7
	s.e.	2.2	2.1	1.8	2.0
	pH	5.4	5.9	4.8	4.9
	s.e.	0.3	0.4	0.5	0.7
	% organic	4.1	1.6	4.3	1.0
	s.e.	0.6	0.4	0.5	0.1
Anions	Soluble sulfur	37.6	33.3	41.7	41.8
	s.e.	6.0	2.5	6.2	4.0
	Phosphorus	34.6	26.8	31.3	14.2
	s.e.	14.6	13.1	6.2	6.8
Exchangeable Cations	Calcium	150.4	202.5	225.7	213.0
	s.e.	31.2	33.7	26.4	67.1
	Magnesium	36.9	36.0	43.5	45.4
	s.e.	4.2	4.9	5.2	10.2
	Potassium	28.9	24.7	28.7	24.8
	s.e.	3.1	3.5	2.5	4.4
	Sodium	27.4	28.7	35.2	36.0
	s.e.	2.4	2.7	3.3	4.6
Extractable micronutrients	Iron	184.9	115.7	210.0	187.2
	s.e.	36.5	14.2	44.9	23.2
	Manganese	2.9	0.5	0.8	0.6
	s.e.	1.7	0.3	0.5	0.6
	Copper	1.5	3.1	1.1	1.6
	s.e.	0.2	1.2	0.2	0.3
	Aluminum	1342.0	1451.2	1287.2	1148.2
	s.e.	136.5	109.4	199.6	118.6
	Zinc	0.9	0.6	1.0	0.4
	s.e.	0.2	0.0	0.2	0.2

Table 1. Soil chemical analysis means for the two groups of forest, older (n=7) and younger (n=6); all concentrations are in ppm. TEC – total exchange capacity.

Organic matter was correlated with soil P levels in the shallower samples when both age stands were combined (Fig. 6). However, the relationship disappeared for the younger stands when analyzed separately, and the relatively small sample size resulted in a barely significant correlation for the older stands. One site (7A) had extremely high levels of phosphorus. There was once a home site in the area of the 7A plot (Larry Walton, Vision Forestry, personal communication), and homestead activities may be responsible for the increased phosphorus there.

Although means were not significantly different, all measurements of depths of litter and organic horizons were greater in the older forests than in the younger (Fig. 7). Beneath the O horizon, most sites had substantially organic surface layers of at least

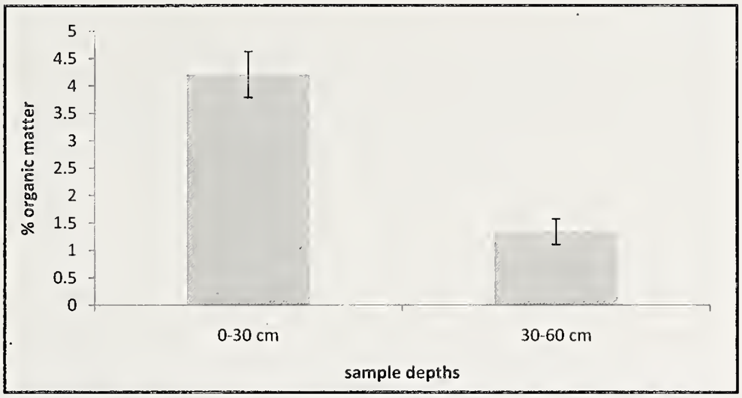

Fig. 5. Percent organic matter of soils as a function of sampling depth averaged over all sites; error bars are ± 1 s.e.

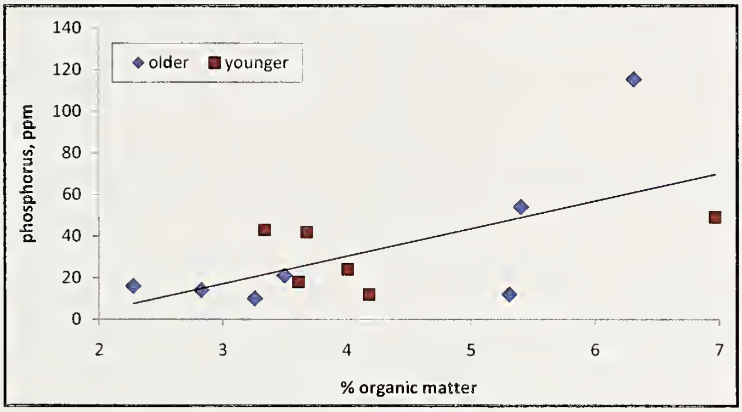

Fig. 6. Relationship between soil phosphorus and organic content in 0-30 cm. depth soil samples; $p = 0.02$, $r2 = 0.47$. Younger sites were not significantly correlated; linear regression analysis of older sites had a significance level of $p = 0.05$; $r2 = 0.56$.

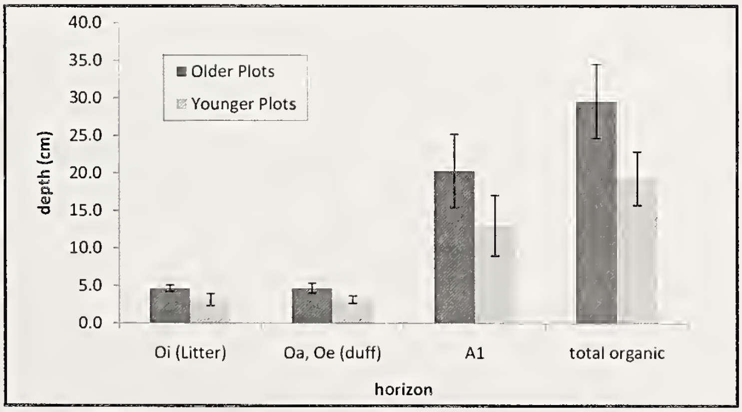

Fig. 7. Depths of organic horizons (O and A1); error bars are ± 1 s.e. Older: n=7; younger: n=6.

10-15cm. depth.

Soil textures were generally sandy loam or sandy clay loam in the A1 horizon, with sand or sandy clay beneath. Often the mineral layer showed a prevalence of oxidized iron compounds, although some sites were characterized by gleying, indicating reducing conditions. At three sites (7B, 8A, and 8B), the deeper sections could not be cored due to extremely hard packed sand or sandy clay.

Coarse Woody Debris

A T-test yielded no significant differences between the means for any of the CWD variables measured. The product of diameter, length, and decay class, as an index of overall CWD abundance, was also analyzed; it, too, did not differ significantly between the older and younger forests. Coarse woody debris frequency generally increases with age of a forest (e.g. Williams and Moriarity 2000) and is an indicator of habitat heterogeneity. Where species of CWD could be determined, the older forests clearly differed, both in the frequency of identifiable pieces and in the prevalence of hardwoods instead of pines. All of the older forests had between one and 10 identifiable coarse woody fragments encompassing nine species; whereas, there were only two younger sites with any identifiable fragments (all pine).

The lack of a difference in abundance of CWD may be explained by the relatively younger age of our "older forests." Alternatively, a higher than expected abundance of CWD in the younger forests could cause them to resemble older ones. More CWD might result in younger forests if silvicultural practices emphasized selective cutting of pines, leaving hardwoods (or seed pines) standing. Such trees are subject to frequent toppling by winds, because they were established with many nearby trees' blocking the wind and competing for light, and hence they are taller and less resistant to wind damage. This type of practice was more common in the past than it is today, although newer forest certification now encourages it as well (Larry Walton, Vision Forestry, personal communication). It is not possible to determine the degree to which this practice was employed in our study areas, however.

	Diameter (cm)	Decay class	Tilt angle (°)	Length (m)	No. pieces
"Older"plots	9.7	3.8	6.6	5.4	14.7
"Younger" plots	10.0	3.8	7.4	4.6	9.3

Table 1. Means by plot age group of coarse woody debris characteristics.

Discussion

A primary objective of ecosystem restoration is the maintenance of biological diversity, which is commonly understood to be enhanced by increased habitat heterogeneity, or spatial variability (Landres et al. 1999). In forests, such heterogeneity may be created by fine-scale disturbance, as in the case of treefall canopy gaps formed from broken tree limbs and large trunks, or of pit and mound features, formed from up-

rooted trees.

Treefall gaps form openings that provide habitat for earlier successional species to invade, and these include shade-intolerant species not found in the undisturbed portion of the forest (Busing 1995). Canopy openings are also important in maintaining the diversity of typical climax species within the canopy itself (Poulson and Platt 1989).

Pit and mound formations are associated with canopy gaps, but they provide the additional feature of elevation difference formed by the uprooted tree, which results in a modified hydrological regime. This fine-scale variability in elevation provides habitat for species with different soil moisture, texture, and nutrient requirements (Titus 1990). These formations may also persist for a much longer time (several centuries) than does a canopy gap formed by a dead or broken tree (Beatty 1984).

In our study, both canopy gaps and uprooted trees were very uncommon in older and younger plots. The scale of microtopography in the plots was considerably finer than that associated with pit and mound formations, which approximate the spatial scale of a tree's root area (Hueneke and Sharitz 1986). There was only one example of such a feature being intersected by the circular transect; this was in a younger forest, where it was formed from a toppled pine.

Pit and mound microtopographic variability is very common in wetland forests (Anderson et al. 2007); in fact, this feature is often used as a field indicator of forested wetland conditions (U.S. Army Corps of Engineers 1987; Al Rizzo, U.S. Fish and Wildlife Service, personal communication). The soft soils of these systems and the shallow roots of wetland tree species such as *Acer rubrum* lead to frequent uprooting of trees. The lack of such features in upland forests in the Coastal Plain region has generally been accepted as typical, and indeed as indicative of upland soil conditions.

However, there are numerous accounts of extensive microtopographic variability in upland forests in other regions. For a New England forest that had not undergone major disturbance since the 1800s or before, Beatty (1984) described pit and mound microtopography as covering 20-50% of the forest floor. Following a major wind disturbance event, Peterson et al. (1990) observed these features over 11% of a Pennsylvania old-growth hemlock-hardwood forest. Tip-up mounds (with no mention of pits) were also present (17.5/ha) in a southern Wisconsin *Acer saccharum* forest presumed to have remained relatively undisturbed for centuries (Struik and Curtis 1962). It is possible that the lack of such features in the region of our study is indicative of insufficient time for their formation, and that the trends we noted in our limited data set are meaningful. Different survey methods, selectively quantifying pit-and-mound formations over a large area, might also disclose greater microtopographic variability, although visual observation of each site was consistent with our survey results.

Forest recovery from disturbance occurs at different rates for different ecosystem components, but in general, it may take longer than the time since disturbance of any of our sites. Duffy and Meier (1989) found no evidence of recovery of understory communities 87 years after clearcutting in an Appalachian forest. They speculated that a

possible cause of this delay is the time required for restoration of pit and mound microtopography. Lorimer (1989) described the abundance of even-aged stands of forests in the Northeast United States produced by widespread commercial logging around 1900, noting that trees in these forests were not large enough to produce substantial treefall gaps when they die. In general, large-scale disturbance, including logging and extensive fires, results in a more even-aged forest of younger trees, which are less likely to produce canopy gaps or to be uprooted.

Our results indicate that upland forests in the study area, subject to relatively recent disturbance in the form of clearcutting, are too young to exhibit substantial microtopographic relief in the form of pits and mounds. However, it is not possible to tell whether this feature would emerge over a much longer time frame of succession, and the historic importance of microtopographic features in these systems is not completely clear. It may be that the current disturbance regime experienced by upland forests in the study area replaced a pre-colonial natural disturbance regime in the form of fires, and neither condition would facilitate the development of pit and mound microtopography.

A survey of witness trees (John Lyon, unpublished, in Maloof 2011) in western Wicomico County indicated a relatively greater historic abundance of pines than is found in our "older" forests of today. The opportunity for pine growth in pre-colonial forests would have required an increased light regime, such as would result from major disturbance. In pre-colonial times, fires appear to have been more frequent than they are today (Kirwan and Shugart 2000; Maloof 2011). Preliminary pollen analyses (Brent Zaprowski, Salisbury University, unpublished) show evidence of substantial clearing in the Nassawango Watershed area beginning in approximately 1200 A.D., and there is other evidence that Native Americans used fire to establish openings in the forests. The frequency and intensity of disturbance generated by fire are difficult to determine. If fires were extensive, relatively large areas of forest may have reached only the mid-successional (subclimax) stage of oak/pine forests, where the potential for pit and mound formation would be minimal.

The paucity of pit and mound formations among the study sites is in stark contrast to both wetland forests in the region and to forests in other geographic areas. Pit and mound microtopography has not been described for upland forests of the coastal plain region, making it even more important to investigate potential true old-growth sites if such can be found. More information is needed to determine the most likely degree and type of disturbance in pre-colonial forests in our region, in order to establish a target for microtopographic variability, but certainly increasing this feature in forest restoration by some means would not be unwarranted if species diversity is to be enhanced. Kuuluvainen et al. (2002) discuss the importance of restoring both canopy gaps and pit and mound microtopography in forest restoration, even going so far as to suggest use of an excavator to topple trees.

Clearly, more work is needed to establish the appropriate target for upland forest

restoration in the Nassawango Watershed. Our study failed to identify model older forests representative of the precolonial period, or even of late stage upland forests of today. However, it is of value to consider the desirability of reproducing a hypothetical intense-disturbance regime within this system. Past history of forest clearing through burning, if prevalent, likely created a mosaic of patches of different-aged stands, with some proportion of older, mature forests containing interior-dwelling species' habitat. In today's landscape, open cover is probably much more common than it was historically, as a result of extensive agriculture and increasing residential development. Attempts to recreate open, burned areas within remaining forests in the Nassawango Watershed, therefore, may have the unintended and undesired result of reducing available mature forest cover to well below that present historically. Management within the existing forests might best focus on reproducing a representative mature forest ecosystem.

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